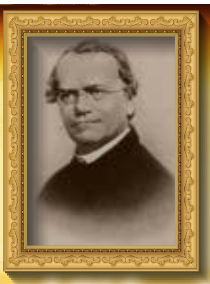
11.1 Monohybrid Inheritance

Definition of Monohybrid Cross

Monohybrid inheritance involves inheritance of one characteristic and contrasting traits controlled by a gene.

History Corner

The study of heredity and the variation of inherited characteristics is called genetics. The first person who scientifically explained the principles of inheritance was Gregor Mendel (Photograph 11.1). Mendel is known as the father of modern genetics.



Photograph 11.1 Gregor Mendel

Mendel Experiments

Mendel figured that pea plants, *Pisum sativum*, possessed seven different characteristics. Pea plants have contrasting traits which are obvious and easy to identify (Figure 11.1). Mendel suggested in his theory that a characteristic in a parent plant is passed down to its next generation through male gametes and female gametes. This shows that the nuclei of the male and female gametes carry genetic materials of the inherited characteristic. The inheritance factor which determines a characteristic is known as a gene.

Career Tips

Careers which involve genetics are genetic counsellors, medical genetic specialists and clinical and medical research officers.

ACTIVITY ZONE

Gather information on the history of Mendel's Laws. Then, present it in your class.

Characteristic	Traits	
	Dominant	Recessive
Seed shape	 Round	 Constricted
Seed colour	 Yellow	 Green
Pod shape	 Inflated	 Constricted
Pod colour	 Green	 Yellow
Flower colour	 Purple	 White
Flower position	 Axial	 Terminal
Plant height	 Tall	 Dwarf

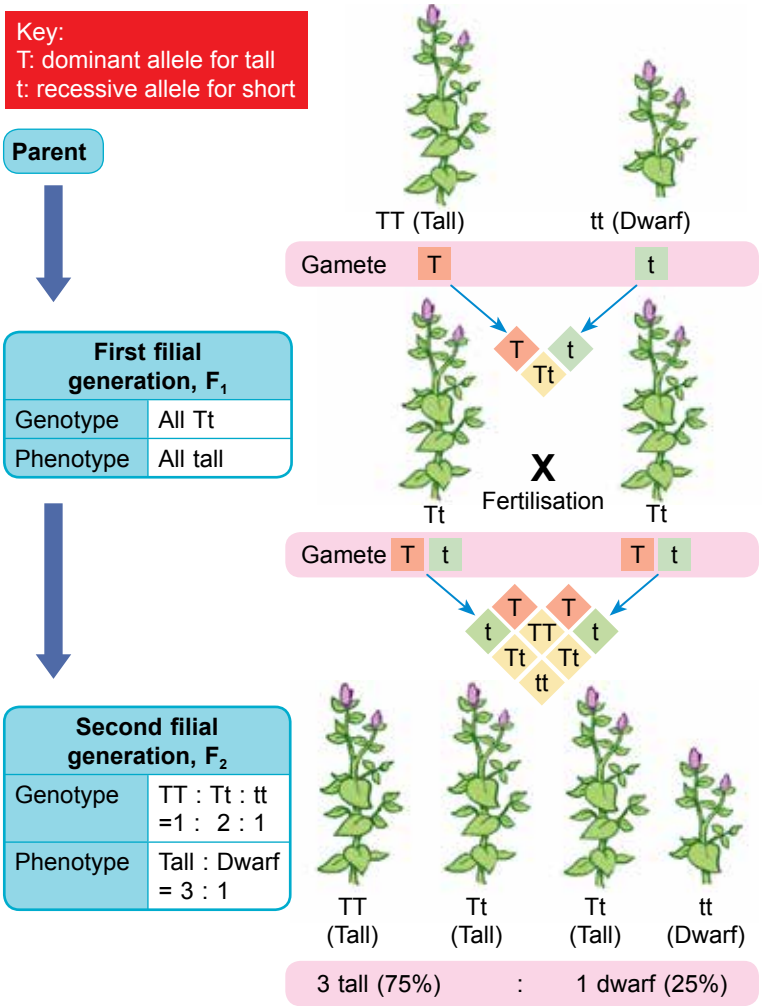
Figure 11.1 Seven characteristics studied by Mendel

In the monohybrid inheritance experiment, Mendel used purebreed pea plants as the parental generation to study the inheritance of pea plant traits. **Purebreed pea plants** are produced through self-cross plant which have similar traits to that of its parent plant in terms of genetic contents. Therefore, self-cross of purebreed tall pea plants produce only tall offsprings.

In the dominance principle, Mendel explained that in a pea plant with a pair of contrasting traits, its trait is determined by a **dominant inheritance factor** whereas another contrasting trait is determined by a **recessive inheritance factor**. The dominant inheritance factor suppresses the effect of the recessive inheritance factor. Hence, the recessive trait is not visible although its inheritance factor exists together with the dominant inheritance factor in a pea plant.

Bio Exploration

Mendel chose the pea plant as his research materials because,
- it can be easily grown and bears many seedlings,
- it has both male and female reproductive structures,
- it has a short generation interval, and
- it possesses contrasting traits or characteristics that are obvious.



Mendel crossed a purebreed tall (TT) pea plant with a purebreed dwarf (tt) pea plant (Figure 11.2).

The cross product between the two purebreed plants was the F_1 generation which consisted of only tall (Tt) pea plants. This shows that the tall trait (T) is **dominant** whereas the dwarf trait (t) is **recessive**.

Mendel then crossed the **F_1 generation** by **self-pollination** (Tt × Tt).

The ratio of tall plant to dwarf plant in **F_2 generation** was **3:1**

Figure 11.2 Monohybrid cross carried out by Mendel

Terms Related to Inheritance

There are a few important genetic terms that you have to understand before you continue to learn more about inheritance.

GENES AND ALLELES

Gene

- A **gene** is the basic unit of inheritance which consists of a DNA segment located on a specific locus of a chromosome.
- A gene controls a specific characteristic of an organism.

Allele

- An **allele** is an alternative form of a gene for a specific trait that is located on the same locus of a pair of homologous chromosomes.

CHARACTERISTICS AND TRAITS

Characteristic

- A **characteristic** is a heritable feature such as height, eye colour, blood group and presence of dimples.
- Each characteristic is a feature of an organism.

Trait

- A **trait** is a variation of a specific characteristic. Each inherited characteristic consists of a specific trait. For example, height is a characteristic whereas tall or dwarf is a trait.

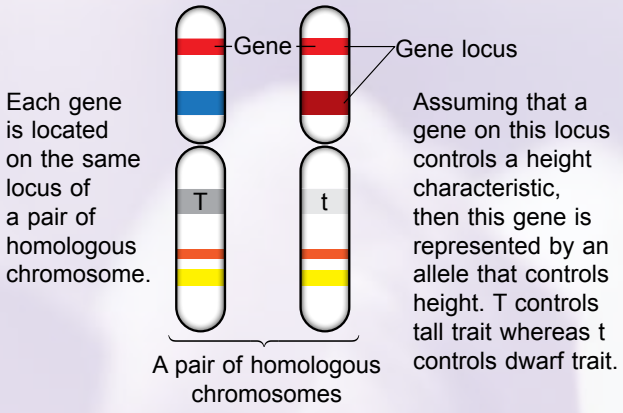


Figure 11.3 Gene locations on homologous chromosomes

PHENOTYPES AND GENOTYPES

Phenotype

- **Phenotype** is the observable characteristic of an organism.
- For example, height.

Genotype

- **Genotype** is the genetic composition of an organism that cannot be seen.
- For example, TT and Tt (genotypes for tall); tt (genotype for dwarf).

Table 11.1 Characteristics and traits

Characteristic	Trait	Genotype	Phenotype
Height	Tall	TT, Tt	Tall
	Dwarf	tt	Dwarf
Colour	Red	RR, Rr	Red
	White	rr	White
Blood group	A	I^AI^A, I^AI^O	A
	B	I^BI^B, I^BI^O	B
	AB	I^AI^B	AB
	O	I^OI^O	O

DOMINANT ALLELES AND RECESSIVE ALLELES

Dominant allele

- **Dominant allele** is an allele which always shows its trait when it is present, and suppresses the effect of recessive allele.
- It is represented by a capital letter. For example, B.

Recessive allele

- **Recessive allele** is an allele which shows its trait when both alleles are recessive allele.
- The effect of recessive allele is suppressed by the presence of dominant allele.
- It is represented by a small letter. For example, b.

HOMOZYGOTES AND HETEROZYGOTES

Homozygote

- Both alleles at loci of a pair of homologous chromosomes are the same. For example, BB or bb.

Heterozygote

- Alleles at loci of a pair of homologous chromosomes are different. For example, Bb.

PARENTAL GENERATIONS AND FILIAL GENERATIONS

Parental generation

- **Parental generation** refers to the first generation of two individuals which are mated to predict or analyse genotypes of their offsprings.

Filial generation

- **Filial generation** refers to a successive generation as a result of mating between individuals of purebreed parental generation.

DOMINANT TRAITS AND RECESSIVE TRAITS

Dominant trait

- Dominant trait is expressed when both alleles are dominant alleles or one dominant allele is paired with a recessive allele.
- For example, BB or Bb.

Recessive trait

- Recessive trait is expressed if a recessive allele is paired with another recessive allele.
- For example, bb.

PUREBREEDS AND HYBRIDS

Purebreed

- **Purebreed** refers to individual which carries two identical alleles for a trait. Self-cross always produces offsprings with the same characteristics in every generation.

Hybrid

- **Hybrid** is the product of mating between two purebreed varieties.

Innovation in Malaysia

In 2019, Malaysian Agricultural Research and Development Institute (MARDI) had successfully produced MR12H, the first hybrid paddy variety, which could increase paddy yield per hectare by up to 20%.

Photograph 11.2 Hybrid flower, *Lilium asiatica*

MEMORI Tip

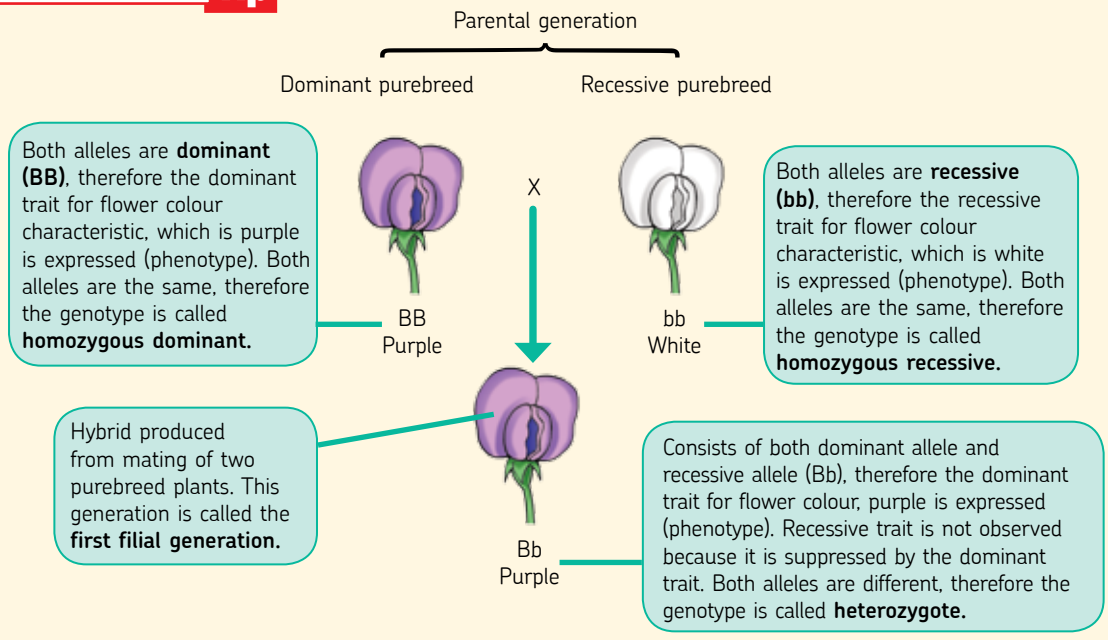
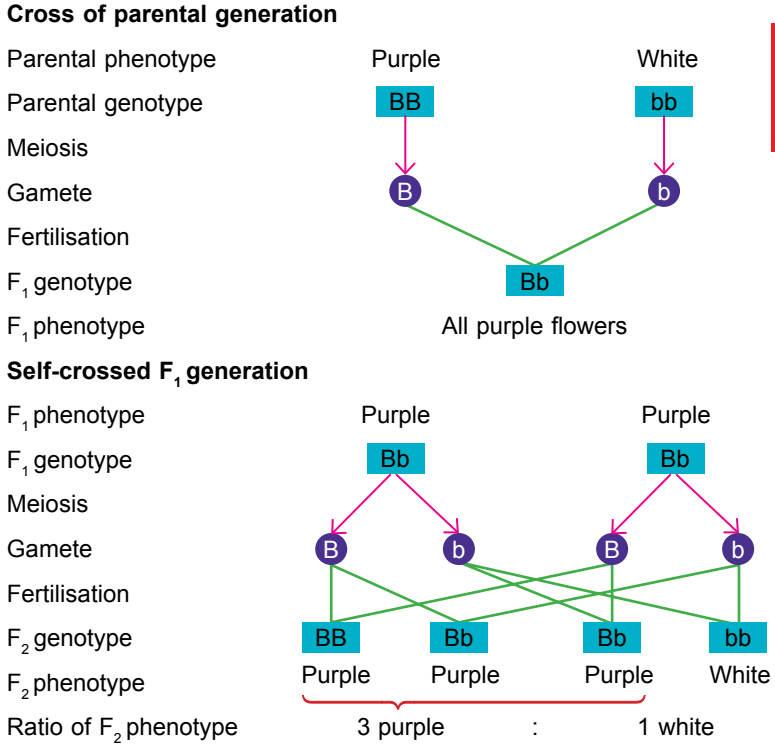


Figure 11.4 Relationship among a few important terms in genetics

How can we explain inheritance of flower colour in Figure 11.4 in a systematic and scientific manner? If allele for the dominant purple trait is labelled B (capital letter), then the allele for recessive white trait is labelled b (small letter). Therefore, each purebreed parent has two identical alleles, either BB for purple flower or bb for white flower.

During formation of gametes, **homologous chromosomes** separate during **meiosis** and produce gametes that carry one B allele from purple flower and one b allele from white flower. Fertilisation between a gamete which carries B allele and a gamete which carries b allele produces offsprings with genotype Bb in the **first filial generation (F_1)**. Since B allele is dominant, the Bb genotype combination expresses only **phenotype** with purple flower. The effect of recessive allele is suppressed by the presence of the **dominant allele**.

If the first filial generation is self-crossed, the **second filial generation (F_2)** will have offsprings with BB, Bb and bb genotypes. BB and Bb genotypes express phenotype with purple flower whereas bb genotype expresses phenotype with white flower. The trait that is not observed in the F_1 generation (white flower colour) reappears in the F_2 generation. The above explanation for inheritance of flower colour can be explained in the form of a schematic diagram of inheritance (Figure 11.5).



Key:
B: dominant allele for purple trait
b: recessive allele for white trait

Bio Exploration

Based on monohybrid cross, Mendel obtained a phenotypic ratio of 2.9:1 in F_2 generation which is close to the ratio of 3:1 if the number of pea plants used was big. Small sample size causes the ratio to be less accurate. In a natural environment, the ratio obtained is dependent on chance and probability. Therefore, the actual ratio of offsprings produced is probably different from the expected ratio.

Figure 11.5 Monohybrid schematic diagram for flower colour characteristic

Based on the fertilisation diagram in Figure 11.5, for monohybrid inheritance, the genotypic ratio in F_2 generation is 1 BB : 2 Bb : 1 bb; whereas the phenotypic ratio in F_2 generation is 3 purple : 1 white. **Punnett square** can also be used to predict the ratios and probabilities of genotype and phenotype in the offsprings produced. Boxes in the Punnett square represent different allelic combinations of zygote or offsprings that are produced (Figure 11.6).

Phenotypic ratio calculation is based on mathematical principle. For example, if the number of round bean seed shape is 5474 and constricted seed is 1850, therefore the ratio is:
Ratio number of round seed : ratio number of constricted seed = (5474 ÷ 1850) : (1850 ÷ 1850) = 2.96 : 1
The value can be rounded up to 3 : 1

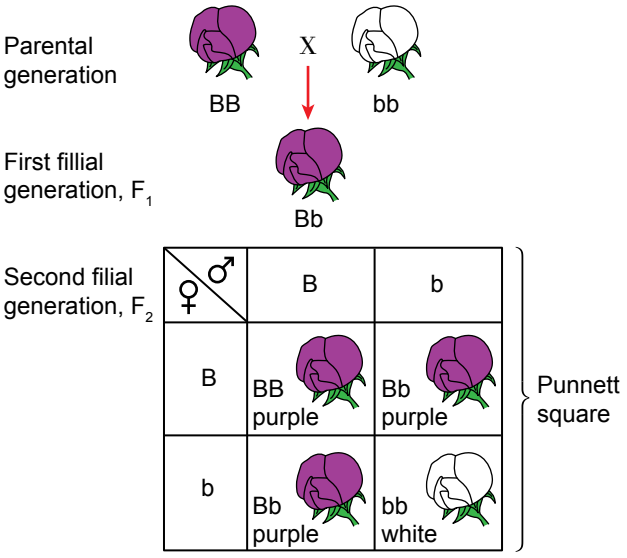


Figure 11.6 Monohybrid cross using Punnett square

11.1.4 11.1.5

Is the phenotypic ratio in monohybrid fertilisation always 3:1? To determine ratio of a monohybrid fertilisation, let's carry out Activity 11.1.

Activity 11.1

21st CENTURY SKILLS: ANALOGY

Aim
To carry out an experiment using beads to illustrate monohybrid fertilisation by analogy

Apparatus
Two black plastic bags, 100 red beads, 100 white beads

Analogy
Red bead represents dominant allele for red-coloured flowers (R)
White bead represents recessive allele for white-coloured flower (r)

Procedure
Fertilisation between two heterozygous or hybrid plants of first filial generation F_1:

1. Place 50 red beads and 50 white beads into the first black plastic.
   This represents pea plants with coloured flowers which are heterozygous.
2. Repeat step 1 with a different black plastic bag.
3. Both plastic bags are shaken to mix the beads well.
4. Without looking into the plastic bags, place a hand inside the first plastic bag and remove one bead. Remove another bead from the second plastic bag.
5. Place both beads on the table. Both beads represent combination of two gametes.
6. Record the probability of genotype and phenotype in F_2 generation in a table.
7. Return the two beads into their respective plastic bags.
8. Ensure that the beads are returned to the correct bags.
9. Repeat steps 3 to 7 for a total of 50 times.
10. Count the total combinations of genotype and phenotype that are produced.

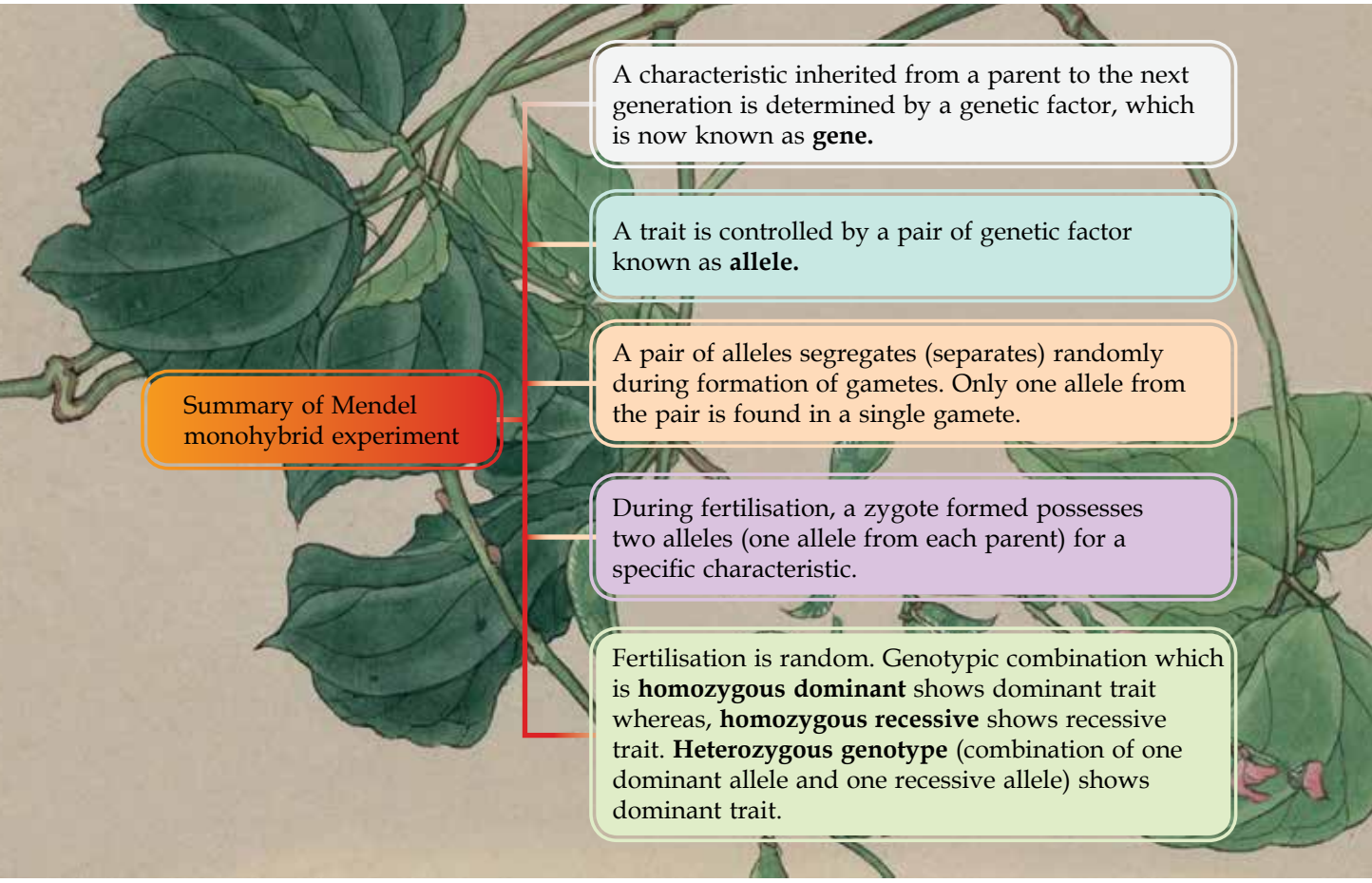
Discussion

1. Which type of inheritance is shown by the characteristic studied in the above experiment?
2. (a) Is the result obtained in accordance with the expected ratio of 3:1?
   (b) Explain your answer.
3. Why is the bead returned into its plastic bag after each observation was recorded?
4. Suggest ways to improve the accuracy of the experiment.

Mendel's First Law

Mendel introduced Mendel's First Law or **Law of Segregation** which states:

> A characteristic of an organism is controlled by a pair of alleles, and only one of the allelic pair is inherited in a gamete.



Summary of Mendel monohybrid experiment

- A characteristic inherited from a parent to the next generation is determined by a genetic factor, which is now known as **gene.**
- A trait is controlled by a pair of genetic factor known as **allele.**
- A pair of alleles segregates (separates) randomly during formation of gametes. Only one allele from the pair is found in a single gamete.
- During fertilisation, a zygote formed possesses two alleles (one allele from each parent) for a specific characteristic.
- Fertilisation is random. Genotypic combination which is **homozygous dominant** shows dominant trait whereas, **homozygous recessive** shows recessive trait. **Heterozygous genotype** (combination of one dominant allele and one recessive allele) shows dominant trait.

Formative Practice 11.1

1. What is meant by purebreed?
2. In a fertilisation between two rats, B represents dominant allele for black fur, whereas b represents recessive allele for white fur. If the outcome of fertilisation is ¼ BB : ½ Bb : ¼ bb, what are the fur colours and genotypes of their parents?
3. Assume that an allele for a tall trait is represented by symbol T and allele for a dwarf trait is represented by symbol t. What are the genotypes and phenotypes of offsprings from a fertilisation between a tall plant and a dwarf plant in which both are purebreed?

11.2 Dihybrid Inheritance

Definition of Dihybrid Cross

Dihybrid inheritance involves inheritance of two characteristics, each characteristic is controlled by a different gene located at a different locus.

Figure 11.7 shows a schematic diagram of a dihybrid inheritance between two purebreed parents to study the characteristics of pea, namely seed colour and seed shape. The two purebreed parents either have a pair of homozygous dominant alleles or a pair of homozygous recessive alleles. Fertilisation between the two purebreed parents produce offsprings in F_1 generation with the dominant traits of round and yellow seeds.

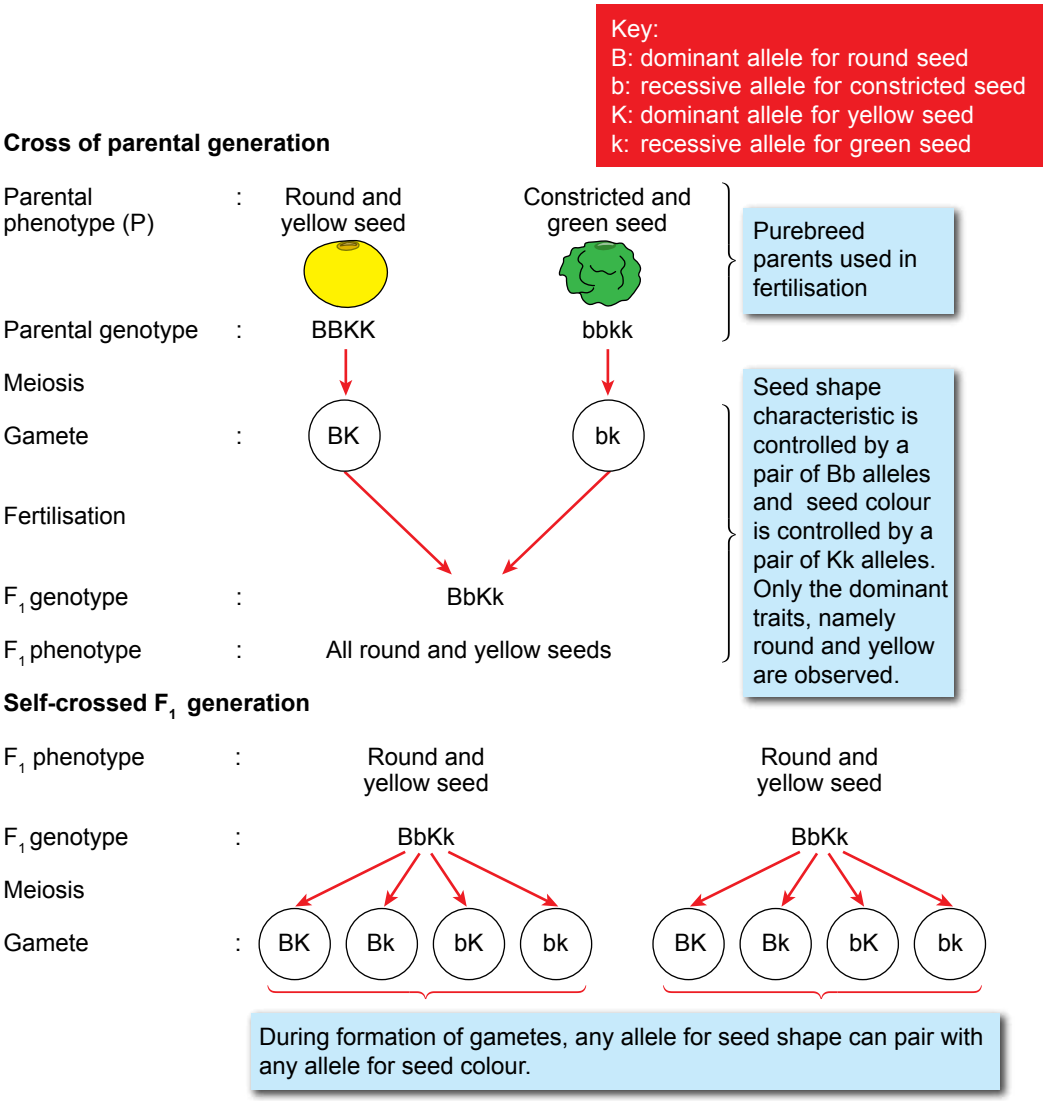


Figure 11.7 Schematic diagram of dihybrid inheritance for seed shape and seed colour of pea plant

11.2.1 11.2.2 11.2.3

When the F_1 generation produced from dihybrid cross in Figure 11.7 was self-crossed, 16 F_2 genotype combinations are produced. The cross shows four phenotypic characteristics in F_2 generation. Outcome of the dihybrid cross is presented in a Punnett square as shown in Figure 11.8.

Female gamete \ Male gamete	BK	Bk	bK	bk
BK	 BBKK Round, yellow	 BBKk Round, yellow	 BbKK Round, yellow	 BbKk Round, yellow
Bk	 BBKk Round, yellow	 BBkk Round, green	 BbKk Round, yellow	 Bbkk Round, green
bK	 BbKK Round, yellow	 BbKk Round, yellow	 bbKK Constricted, yellow	 bbKk Constricted, yellow
bk	 BbKk Round, yellow	 Bbkk Round, green	 bbKk Constricted, yellow	 bbkk Constricted, green

Figure 11.8 Dihybrid cross of F_1 generation using Punnett square

Phenotypic ratio produced in F_2 generation:

 Round, yellow seed 9 :  Round, green seed 3 :  Constricted, yellow seed 3 :  Constricted, green seed 1

Mendel's Second Law

Mendel introduced Mendel's Second Law, also known as **Law of Independent Assortment** which states:

> During gamete formation, each allele from a pair of alleles can combine randomly with any allele from another pair of allele.

Summary of Mendel dihybrid experiment

- New combinations of characteristics are produced in the F_2 generation namely constricted yellow seed and round green seed.
- Two characteristics (seed shape and colour) are combined in F_1 generation but later they separate and react freely in F_2 generation.

ACTIVITY ZONE

Gather information on Mendel's Second Law of Inheritance. Then, present it in your class.

11.2.4 11.2.5

Formative Practice 11.2

1. Mendel performed cross between pea plants to study two characteristics, namely flower position and flower colour. Which type of inheritance is this?
2. The following table shows dihybrid cross between two pea plants.

Parental phenotype	Round and yellow seed	Constricted and green seed
Parental genotype	RrYy	rryy

Key:
R: dominant allele for round seed
r: recessive allele for constricted seed
Y: dominant allele for yellow seed
y: recessive allele for green seed

Which F_1 generation phenotypes are probably produced?

11.3 Genes and Alleles

Definition of Locus

Locus is a specific location of a gene in a chromosome.

Each chromosome carries many genes. In human, the number of genes that code for proteins in a set of haploid chromosome is estimated to be 25 000.

Allele which represents a gene is located at the same locus as the gene. Figure 11.9 shows five genes with their respective alleles on specific loci of a pair of homologous chromosome.

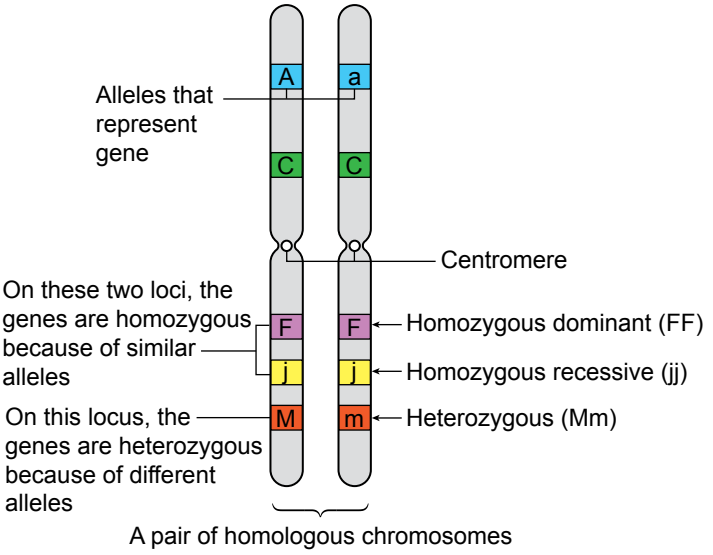


Figure 11.9 Locus, gene and allele on a pair of homologous chromosomes

11.2.5 11.3.1 11.3.2

Activity 11.2

21st CENTURY SKILLS: ANALOGY

Aim

Make analogy to relate allele, locus and gene of a chromosome

Procedure

1. Work in pairs.
2. Figure 11.10 shows an example of an analogy to relate allele, locus and gene on a chromosome.
3. Think and draw an example of another analogy to relate allele, locus and gene on a chromosome.
4. Present your analogy in class

Chromosome:
Shopping mall X

Locus:
Level 1 car park, boxes 212, 213, 214

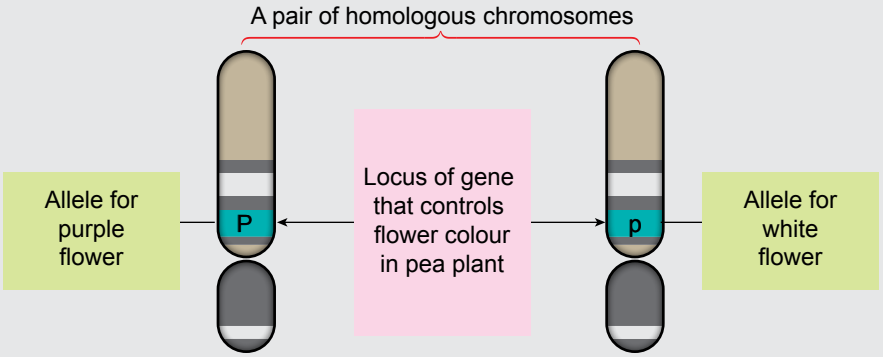
Gene:
Sedan car

Allele:
Sedan car model P
Sedan car model Q
Sedan car model R

Figure 11.10 Example of analogy of alleles, loci and genes on a chromosome

Formative Practice 11.3

1. State the meaning of:
   (a) locus
   (b) allele
2. Based on the figure below, explain the relationship between locus, gene and allele.



11.4 Inheritance in Humans

There are two types of human chromosomes, namely **autosomes** and **sex chromosomes** (Table 11.2). Human somatic cell consists of **44 autosomes** and **2 sex chromosomes**. Autosomes vary in terms of size and length.

Table 11.2 Types of human chromosomes

	Autosome	Sex chromosome
Feature	Consists of chromosome pairs from number 1 to 22	Consists of one chromosome pair, that is number 23
Function	Controls all characteristics of somatic cells	Consists of genes which determine gender
Example	Types of blood groups, height and skin colour	Male has XY chromosomes whereas female has XX chromosomes

Bio Exploration

Male sex chromosomes of XY are different in size. X chromosome is longer than Y chromosome. Y chromosome only carries genes which determine sex characteristics.

The number and structure of chromosomes present in a cell nucleus is known as **karyotype** (Figure 11.11). Chromosomes are arranged in pairs, based on homologous chromosomes in terms of their **sizes**, **centromere locations** and **banding pattern** of chromosomes.

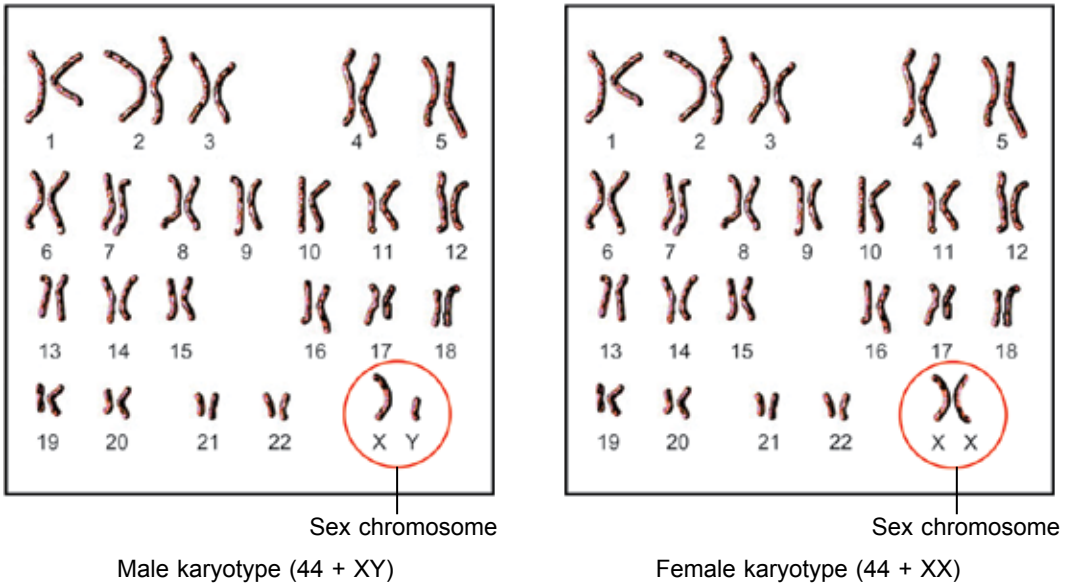


Figure 11.11 Human karyotype

11.4.1 11.4.2

Let's carry out Activity 11.3 to understand how human chromosomes are arranged to obtain a karyotype as performed by a geneticist.

Activity 11.3

21ST CENTURY SKILLS ANALOGY

Aim

To match chromosomes from father (paternal) and chromosomes from mother (maternal) in a human chromosome chart to build a complete karyotype of an individual

Materials

Printed photographs of human chromosomes, blank papers

Apparatus

Scissors, glue

Procedure

1. Obtain printed photographs of human chromosomes from your teacher.
2. Build a complete karyotype of an individual by matching paternal chromosomes and maternal chromosomes using micrographs of human chromosomes from the printed photographs given.
   (a) Cut and paste pairs of homologous chromosomes by arranging them from the biggest and the longest to the smallest and shortest.
   (b) Provide a number for each pair of homologous chromosomes based on its size and length.
   (c) Complete the karyotype arrangement by placing a pair of sex chromosomes at the last position.

Changes in number of chromosome can occur due to failure of homologous chromosomes to separate during **anaphase I** or failure of sister chromatids to separate during **anaphase II**. This disorder is known as nondisjuction which can occur in some chromosomes. When nondisjunction occurs in humans, either male gamete (sperm) or female gamete (ovum) can possess chromosome number of less than 23, that is 22 or more than 23, which is 24. Therefore, fertilisation that involves the abnormal gamete with a normal gamete produces a zygote with **45 chromosomes** or **47 chromosomes**. Examples of genetic diseases caused by nondisjunction are **Down syndrome** (Figure 11.12), **Turner syndrome** (Figure 11.13) and **Klinefelter syndrome** (Figure 11.14).

- Total chromosome number is 47, which is **45 + XY**. There is an extra chromosome for chromosome pair number 21.
- Down syndrome is also known as **trisomy 21**. Down syndrome can occur in both males and females.

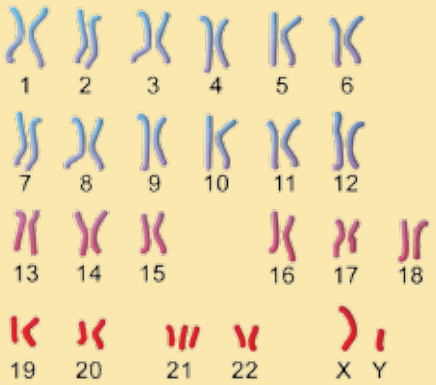


Figure 11.12 Karyotype of a male with Down syndrome

11.4.3

- In **Turner syndrome**, total number of chromosomes is 45, which is **44 + XO**.
- There is a missing X chromosome in the pair of sex chromosomes.
- The gender of individual with Turner syndrome is a female.

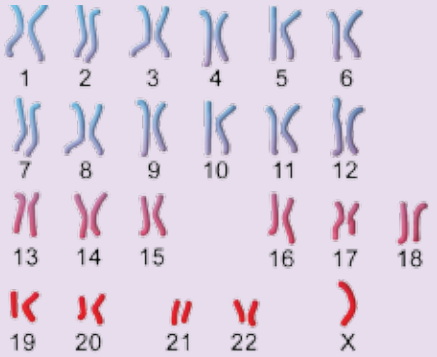


Figure 11.13 Turner syndrome karyotype

- Karyotype of **Klinefelter syndrome** has a total of 47 chromosomes, that is **44 + XXY**.
- There is an extra X chromosome in the pair of sex chromosomes. The gender of individual with Klinefelter syndrome is male.
- However, his secondary sex characteristics are not well-developed.

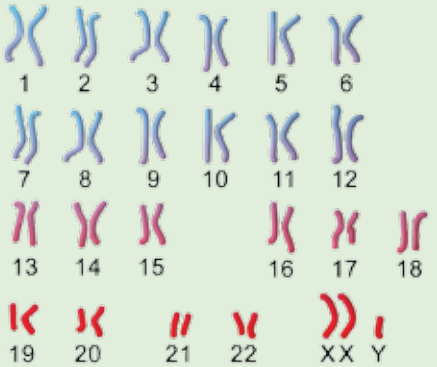


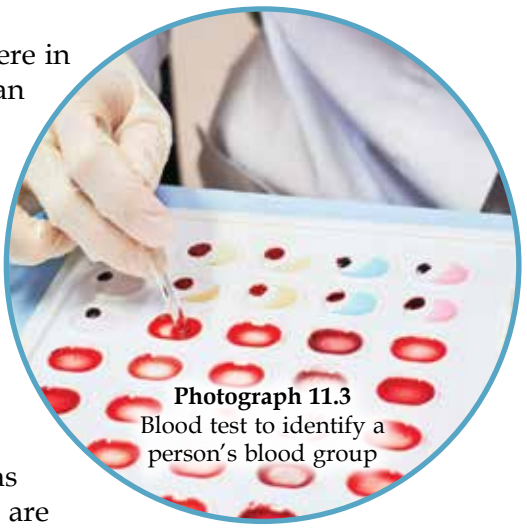
Figure 11.14 Klinefelter syndrome karyotype

Human Inheritance

ABO Blood Groups

You have learnt about the ABO blood group when you were in Form 4. As you already know, in ABO blood group, human blood is classified into **A**, **B**, **AB** and **O**.

ABO blood group in humans is an example of multiple alleles. Blood group is controlled by a gene which consists of three different alleles, namely **allele I^A, I^B** and **I^O**. These alleles determine the types of antigens present on the surface membrane of red blood cells. However, a person only possesses two alleles to determine his/her blood group.



Photograph 11.3 Blood test to identify a person's blood group

Both I^A and I^B are dominant alleles whereas I^O is recessive allele. Therefore, a combination of I^A and I^O (I^AI^O) alleles expresses a group A blood phenotype whereas I^BI^O expresses a group B blood phenotype. I^A and I^B alleles are **codominant** to one another. When these two alleles are present together, effects of both alleles show. A combination of both alleles gives an AB blood group phenotype. Table 11.3 shows a summary of phenotype and genotype human ABO blood group.

11.4.3 11.4.4

Table 11.3 Phenotype and genotype of human blood group

Phenotype (blood group)	Genotype
A	I^AI^A or I^AI^O
B	I^BI^B or I^BI^O
AB	I^AI^B
O	I^OI^O

Key:
I^A and I^B: dominant allele
I^O: recessive allele

How do you solve a blood group inheritance issue in the following problem?

A man with A blood group married a woman with B blood group. Explain the probability of the couple in getting a child with O blood group.

Answer:
Both mother and father are heterozygous for A blood group and B blood group.
Schematic diagram for blood inheritance is shown in Figure 11.15.

Bio Exploration

Inheritance of blood group is an example that does not follow Mendel's Law. According to Mendel, one gene only has two alleles (one dominant allele and one recessive allele).

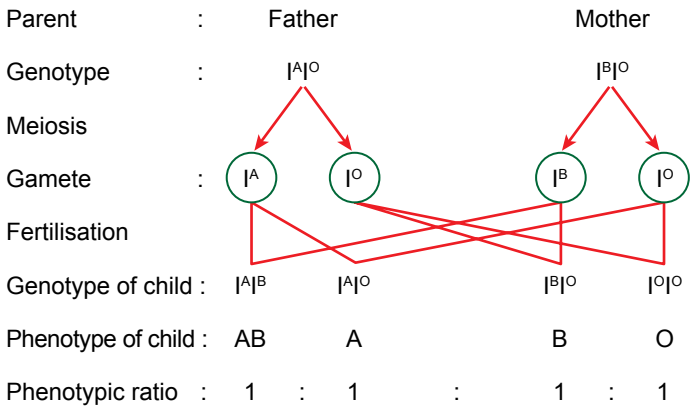


Figure 11.15 Schematic diagram of ABO blood group inheritance

Rhesus Factor (Rh)

Besides **antigen A** and **antigen B** on the surface of human red blood cell, there is another antigen called **antigen D** which is known as **Rhesus factor (Rh)**. An individual whose red blood cell has Rhesus factor is said to be **Rhesus positive (Rh^+)** whereas an individual without the Rhesus factor is said to be **Rhesus negative (Rh^-)**.

Inheritance of Rhesus factor from parents to children is based on principles of Mendel's Law. Rhesus factor is controlled by genes which consists of a pair of alleles, namely **Rh^+ dominant** and **Rh^- recessive**. Genotype of an Rh positive individual is either **homozygous dominant** (Rh^+Rh^+) or **heterozygous** (Rh^+Rh^-). Rh negative individual is **homozygous recessive** (Rh^-Rh^-). Figure 11.16 shows inheritance of Rhesus factor. Can you build a schematic diagram based on Figure 11.16 below?

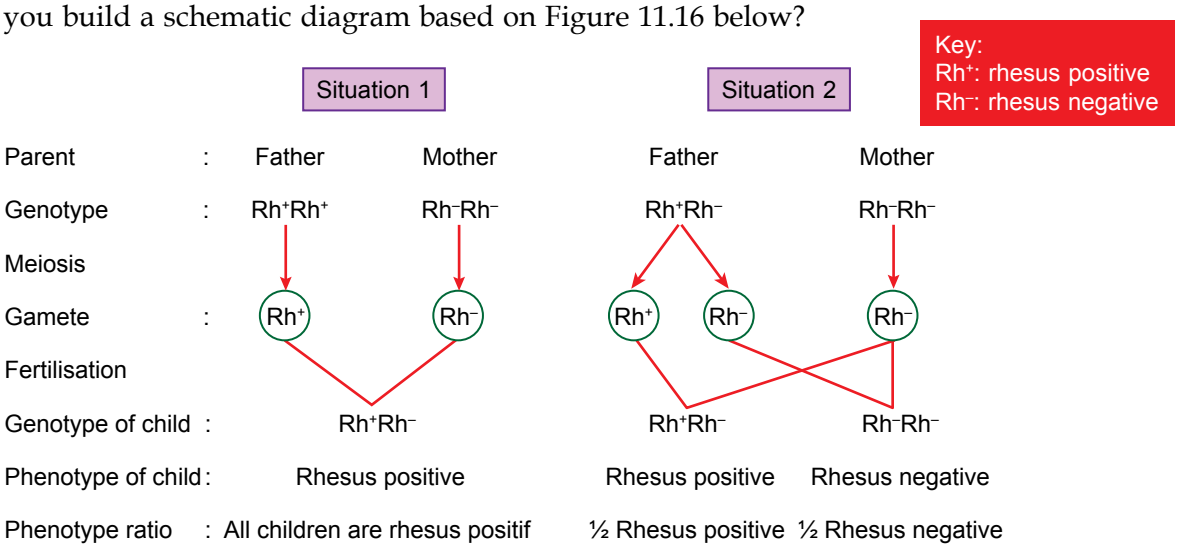


Figure 11.16 Schematic diagram of Rhesus factor inheritance

Thalassemia

Thalassemia is an inherited disease. The disease can be passed down from generation to generation.

Thalassemia is due to **gene mutation** on an **autosome**, that is on chromosome **11** or **16**. Thalassemia is due to the abnormality and low number of haemoglobin. The red blood cell is smaller and paler. Figure 11.17 shows the probability of inheriting thalassemia.

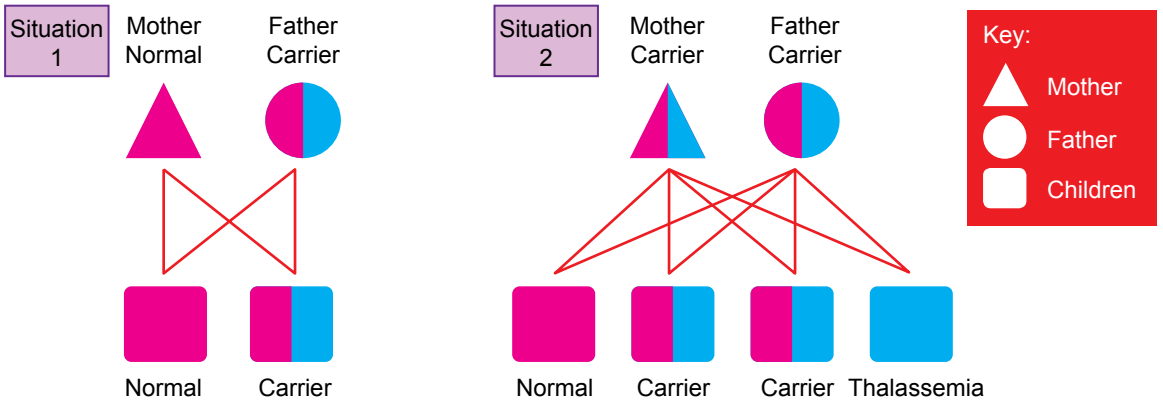


Figure 11.17 Inheritance of thalassemia

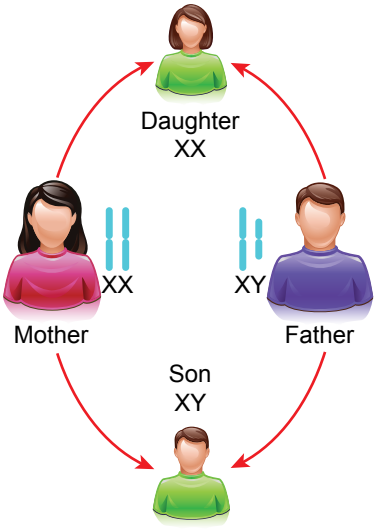
Thalassemia carrier is said to have a **thalassemia minor** condition in which the individual possesses recessive allele of thalassemia but the individual does not show any symptoms of the disease. Detection of thalassemia can only be confirmed by a blood test. A **thalassemia** patient is said to have **thalassemia major** when the individual has both the recessive alleles. A thalassemia patient shows symptoms such as tiredness, paleness, breathing difficulty and changes in facial bone formation from the age of 3 to 18 months.

History Corner

Thalassemia screening programme to identify thalassemia carriers among form four students was launched in 2016 by the Ministry of Health Malaysia.

Sex Determination

A male has **44 + XY** chromosomes and a female has **44 + XX**. Sperms produced in the testis are haploid, and each sperm has either **22 + X** or **22 + Y** chromosomes. Secondary oocytes produced in the ovary are also haploid and each secondary oocyte has only one set of chromosome, namely **22 + X** chromosomes. Sex or gender of a child is determined during fertilisation (Figure 11.18).



Parent	:	Father	Mother
Genotype	:	44 + XY	44 + XX
Meiosis			
Gamete	:	22 + X, 22 + Y	22 + X
Fertilisation			
Genotype of child	:	44 + XX	44 + XY
Phenotype of child	:	Female	Male
Phenotypic ratio	:	1 :	1

Figure 11.18 Determination of children's gender

Sex-linked Inheritance

Genes located on sex chromosomes which control specific characteristics but are not involved in sex determination are known as **sex-linked genes**. Genes of **colour blindness** and **haemophilia** are located in the X chromosome. These genes are called **sex-linked genes**. Characteristics of colour blindness and haemophilia are caused by recessive genes linked to X chromosome. Y chromosome is shorter than X chromosome and does not contain as many alleles as X chromosome. Therefore, any traits in males caused by either the dominant allele or recessive allele on chromosome X is observed.

Colour Blindness

Colour blindness is a condition in which a person cannot differentiate some specific colours such as red and green. Colour blindness is caused by the recessive allele found in the X chromosome and most people with colour blindness are males.

In sex-linked inheritance research, X and Y chromosomes must be shown when writing the genotypes. Dominant allele is represented by a capital letter whereas recessive allele is represented by a small letter on the X chromosome. Genotypes of colour blindness inheritance are written as shown in Table 11.4.

Table 11.4 Genotype and phenotype of colour blindness inheritance

Phenotype	Genotype	
	Male	Female
Normal	X^BY	X^BX^B
Carrier	–	X^BX^b
Colour blind	X^bY	X^bX^b

Key:
X^B: dominant allele
X^b: recessive allele

Figure 11.19 shows a schematic diagram for colour blindness when a man with normal eyesight marries a woman who is heterozygous for colour blindness.

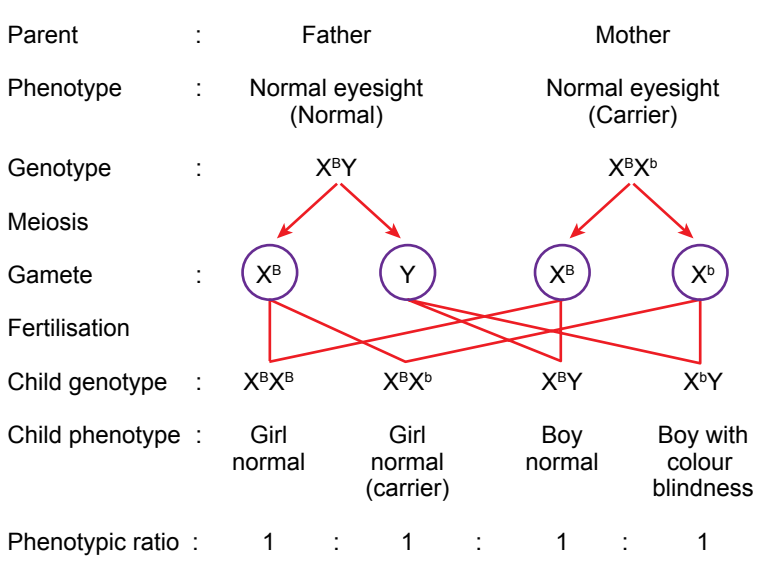


Figure 11.19 Schematic diagram of colour blindness inheritance

ACTIVITY ZONE

Perform Ishihara test to identify colour blindness among friends in your class.

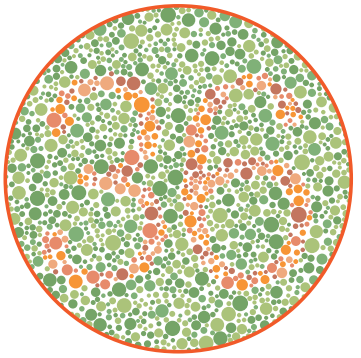


Figure 11.20 An example of Ishihara test plate

Bio Exploration

Ishihara test is a famous colour blindness screening test that has been used worldwide since 1917. The test was developed by Shinobu Ishihara (1879 - 1963), a Japanese opthalmologist. It is invented to screen for the common green-red colour blindness defects. Individuals with normal eyesight can identify the numbers or pattern in the Ishihara test plates (Figure 11.20) whereas individuals with colour blindness defects would report wrong numbers or fail to identify the numbers and patterns.

Haemophilia

Haemophilia is a condition in which blood cannot clot in normal circumstances due to the lack of blood clotting factor. This can result in excessive internal or external bleeding which may be fatal. Haemophilia is due to the presence of the **recessive allele** in the **X chromosome**, which causes the male to be haemophilic. The female will only be haemophilic if both recessive alleles are present on both X chromosomes. Table 11.5 shows how genotypes and phenotypes are written in a haemophilic inheritance. Figure 11.21 shows a schematic diagram for haemophilia inheritance.

Table 11.5 Genotypes and phenotypes of haemophilic inheritance

Phenotype	Genotype	
	Male	Female
Normal	X^HY	X^HX^H
Carrier	-	X^HX^h
Haemophilic	X^hY	X^hX^h

Key:
X^H: dominant allele
X^h: recessive allele

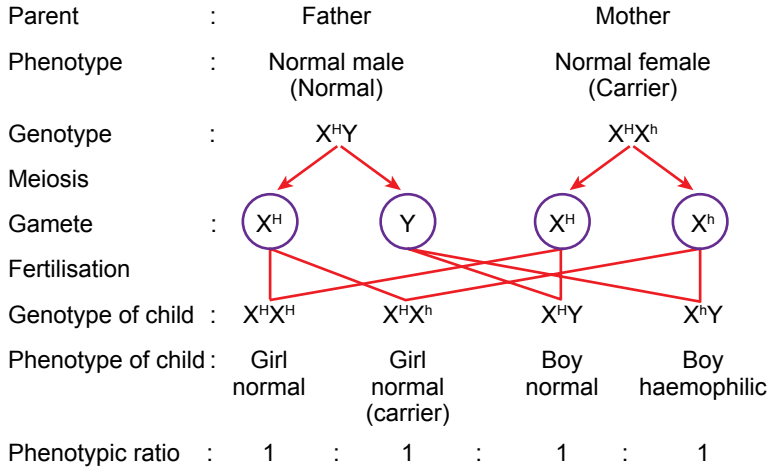
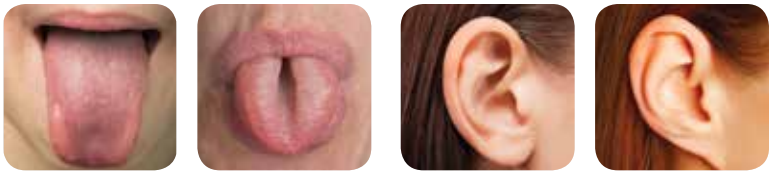


Figure 11.21 Schematic diagram for haemophilia

Ability to Roll Tongue and Types of Earlobe

The ability to roll tongue and the types of earlobes (Photographs 11.4 (a) and (b)) are two characteristics that can be inherited from parents to children according to Mendel's Law. Ability to roll tongue is a dominant trait. Free earlobe is a dominant trait whereas attached earlobe is a recessive trait.



(a) Ability to roll tongue (b) Type of earlobe

Photograph 11.4

ICT

Info

Ability to roll tongue and type of earlobe
http://bukuteksksm.my/Biology/F5/Pg249.pdf

11.4.4 11.4.5

Family Pedigree

Family pedigree or lineage can be analysed to investigate inheritance of human characteristics. Family pedigree is a flowchart through a few generations to show **ancestral relationship** and **inheritance of characteristics** from ancestors to individuals in the present generation.

Analysis of family pedigree enables the geneticist to predict an inherited characteristic of interest and also to identify the features of dominant or recessive gene. Normally a dominant gene appears in every generation whereas a recessive gene is probably hidden in certain generations. Figure 11.22 shows a pedigree chart of a family for three generations. Based on the figure, can you explain the inherited disease in the family?

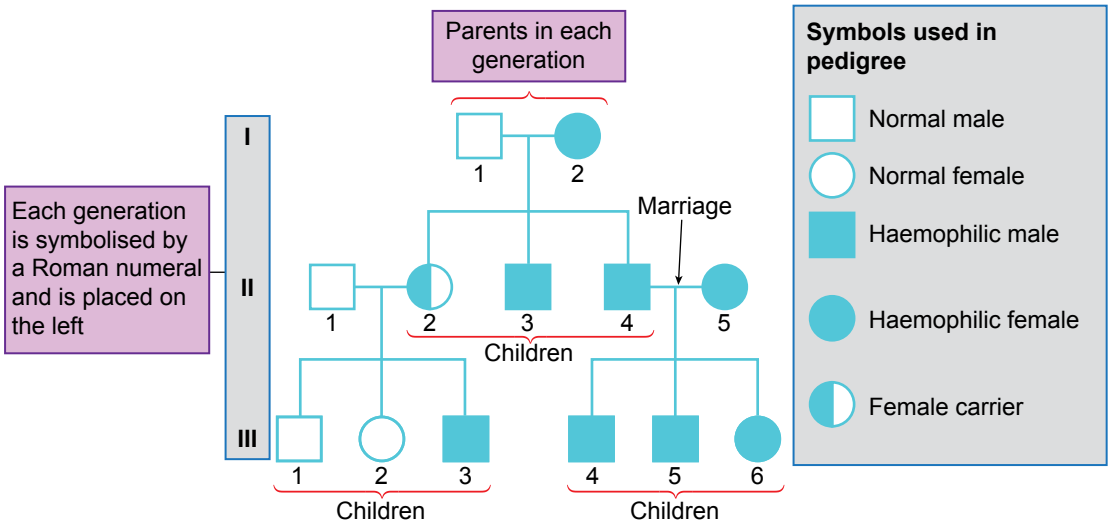


Figure 11.22 Haemophilic inheritance in a family

Activity 11.4

Aim

To build a family pedigree based on phenotypic and genotypic information of family members

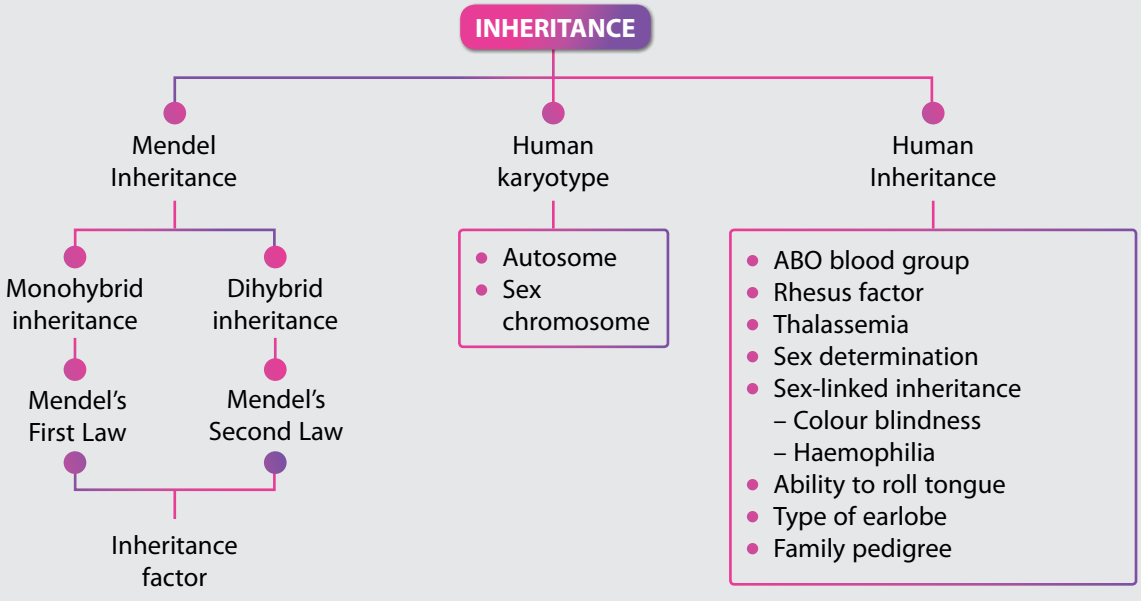
Procedure

1. Carry out the activity individually.
2. Observe one characteristic (phenotype) that is inherited in your family.
3. Beginning with you, build a family pedigree chart through a few generations to show the inherited characteristic that you investigate.
4. Present the family pedigree chart that you built in your class.

Formative Practice 11.4

1. A woman has heterozygous B blood group and a man has heterozygous A blood group. If the couple has an unidentical twins, what are the chances of both children having A blood group? Explain the inheritance of blood group of this family by using a schematic diagram using appropriate symbols.
2. A woman who is heterozygous for haemophilia married a normal man. What are the chances of the couple having a haemophilic son?
3. A man who is homozygous for the ability to roll his tongue married a woman who is heterozygous for tongue rolling. What are the implications of their mating?

Memory Flashback



Interactive Bio 11

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of monohybrid inheritance		
Monohybrid cross based on Mendel's experiment		
Terms related to inheritance		
Schematic diagram for monohybrid inheritance		
Mendel's First Law		
Dihybrid cross based on Mendel's experiment		
Schematic diagram for dihybrid inheritance		
Mendel's Second Law		
Meaning of locus		
Relationship of allele, locus and gene on a chromosome		
Types of human chromosomes		
Human karyotype and genetic diseases		
Mendel's Laws and inheritance in humans		
Family pedigree		

Summative Practice 11

1. Figure 1 shows a cross between two pea plants, X and Y. If:

P : dominant allele for purple flower
p : recessive allele for white flower
S : dominant allele for inflated pod
s : recessive allele for constricted pod

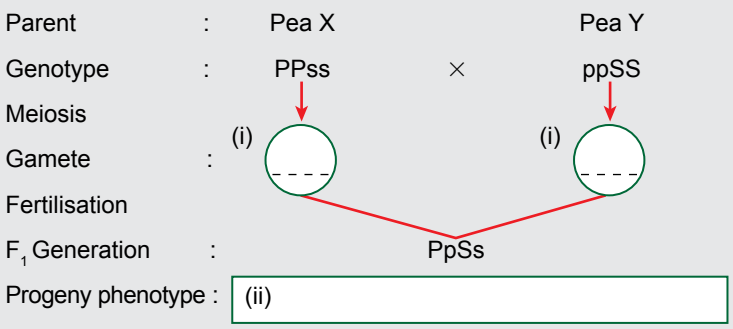


Figure 1

(a) State the phenotypes of parental plants X and Y.

(b) Complete the gamete genotypes produced by each parent, and phenotypes in F_1 generation in Figure 1.

(c) Table 1 shows the genotypes of F_2 generation after F_1 was crossed with another F_1 generation. The total number of F_2 progenies was 16.

Table 1

Gamete	PS	Ps	pS	ps
PS	PPSS	PPSs	PpSS	PpSs
Ps	PPSs	PPss	PpSs	Ppss
pS	PpSS	PpSs	ppSS	ppSs
ps	PpSs	Ppss	ppSs	ppss

(i) State the probability of the pea plant in F_2 generation with purple flower and constricted pod.

(ii) State the probability of the pea plant in F_2 generation with purple flower and inflated pod.

(iii) In Table 1, circle the genotypes of pea plant in F_2 generation with white flower and inflated pod. Then, determine the probability of F_2 generation for the phenotypes.

(d) State the phenotypic ratio of the progeny in F_2 generation.

Purple flower, inflated pod	Purple flower, constricted pod	White flower, inflated pod	White flower, constricted pod
_____	_____	_____	_____

(e) Based on Figure 1 and Table 1, state Mendel's Second Law.

2. A man has normal eyesight whereas his wife is colour blind. X^B is a dominant allele for normal eyesight whereas X^b is a recessive allele for colour blindness. What is the probability of their children having:

(a) Colour blindness?

(b) Normal eyesight but a carrier?

Explain your answers using a schematic diagram.

21st Century Mind

3. In a type of cattle, white face and long horns are dominant traits as opposed to those with black face and short horns as shown in Photograph 1. A breeder plans to breed all white face and long horns cattle in his farm. Prior to that, he has to ensure that his bull and cow are purebreed. As a geneticist, explain how you can assist the breeder in determining whether his cattle is purebreed or hybrid?

Photograph 1

Chapter 12

Variation

Chapter Exploration

- Types and Factors of Variation
- Variation in Humans
- Mutation

Learning Standards

Do You Know?

- What are the existing types of variations?
- What are the differences between continuous and discontinuous variation?
- Can you give examples of variation in humans?
- What is the meaning of mutation?

CCR5 GENE MUTATION

Human Immunodeficiency Virus (HIV) invades the human body by entering the cell through CD4 receptor and CCR5 co-receptor found on the cell surface. Medical experts in Washington found an extraordinary mutation on CCR5, which is called CCR5 gene mutation. The mutation prevents HIV from entering the human cell and infecting the human body.

CCR5 gene mutation was discovered in an AIDS patient who recovered from HIV infection after undergoing a bone marrow transplant from a donor who had CCR5 gene mutation .

Keywords

- Survival of species
- Natural selection
- Continuous variation
- Discontinuous variation
- Mutagen
- Mutation
- Mutant
- Gene mutation
- Chromosomal mutation
- Crossing over
- Independant assortment of chromosomes
- Random fertilisation

12.1 Types and Factors of Variation

Definition of Variation

Variation refers to the differences in characteristics found within the same population or species.

No two organisms are the same although they are from the same species including identical twins (Photograph 12.1). There will always be differences between them. Normally, variation refers to physical characteristics observed in phenotypic differences caused by changes in structure, physiology and biochemistry. Variation enables us to identify individuals within a population.

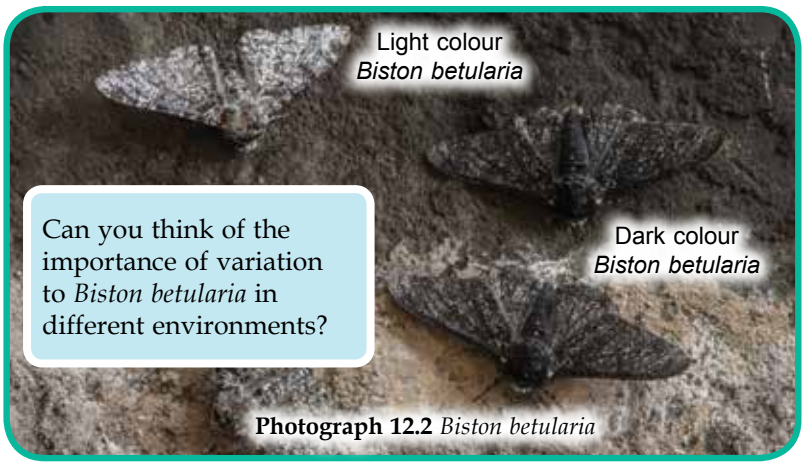
Photograph 12.1 Identical twins

Think Smart

Do identical twins have variation in their phenotypes? Why?

The Necessity of Variation for the Survival of Species

Variation plays an important role in evolution and forms the basis of natural selection. Natural selection is an evolutionary force that selects beneficial genes and removes the non-beneficial ones from the natural environment. Through natural selection, species that possess phenotypes which enable them to adapt to their surrounding will continue to live and breed for the survival of the species (Figure 12.1).



Photograph 12.2 *Biston betularia*

Bio Exploration

The industrial revolution in the United Kingdom caused environmental pollution. *Biston betularia* which is darker in colour survives better compared to the one in bright colours because it is not easily seen by birds of prey (Photograph 12.2).

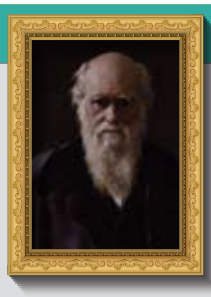
12.1.1 12.1.2

Necessity of variation

- Enables natural environment to continue selecting beneficial characteristics and remove the non-suitable ones
- Ensures survival of the species when the environment changes
- Allows cross breeding among species to form new species

Figure 12.1 Necessity of variation

ACTIVITY ZONE



Photograph 12.3
Charles Darwin

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change..."

– Charles Darwin

Charles Darwin (1809 – 1882) is the scientist who pioneered the evolution theory based on natural selection as described in his book Origin of Species. Describe your opinion on the above statement by Darwin.

Activity 12.1

21st CENTURY SKILLS
INDIVIDUAL PRESENTATION

Aim
Collect information and present your opinion on variation in various animals and plants

Procedure
1. Work in groups.
2. Search for information on the Internet on variation of animals and plants.
3. Present the findings of your group using multimedia presentation.

12.1.1 12.1.2

Types of Variation

The two types of variation are **continuous variation** and **discontinuous variation.**

Continuous variation

- **Continuous variation** is the variation in which the differences in the characteristic is not distinct. Individuals show gradual differences in characteristic from one extreme to the other extreme. A spectrum of phenotype is observed.
- If data is obtained and plotted on a graph, a **normal distribution** or a **bell-shaped curve** will be obtained. Most members of the population have intermediate phenotypes, which are characteristics found in between the two extremes. (Figure 12.2).
- Continuous variation is **quantitative**, it can be measured and graded from one extreme to the other extreme.
- The characteristics are influenced by environmental factors. Examples of characteristics which show continuous variation are **height**, **body weight** and **skin colour** (Photograph 12.4).

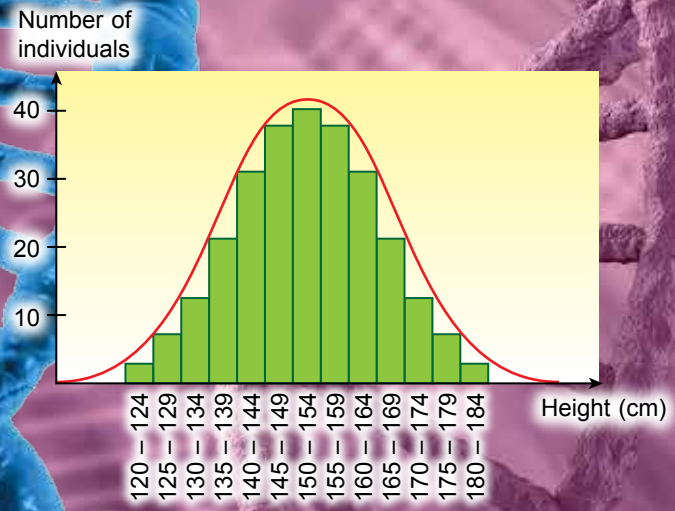


Figure 12.2 Graph of continuous variation

Photograph 12.4 Examples of characteristics that show continuous variation

Types of Variation

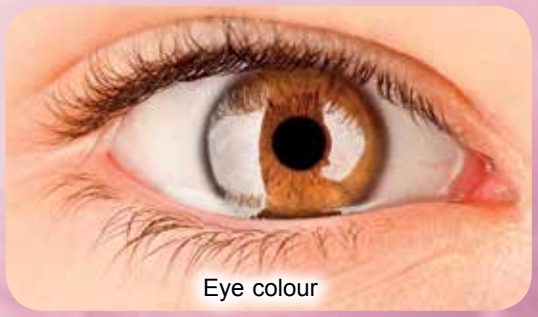
Discontinuous variation

- **Discontinuous variation** shows distinct differences in characteristic.
- If data is obtained and plotted on a graph, a **discrete distribution** or a bar chart with separate bars are obtained. There are no intermediate characteristics (Figure 12.3).
- The characteristic is **qualitative**, it cannot be measured or graded because the characteristic can only be determined by genetic factor.
- The characteristic is not influenced by environmental factors.
- Occurence of discontinuous variation is due to genetic factors, therefore it can be inherited.
- A characteristic is determined by a single gene with two or three alleles. Therefore, the characteristic is easily seen.
- Examples of discontinuous variations are the **ability to roll tongue, eye colour** and **fingerprint pattern** (Photograph 12.5).

Bio Exploration

A total of 8%–10% of the human population worldwide has blue eyes, which is caused by low level of melanin content in the outer layer of iris.

Ability to roll tongue



Eye colour

Photograph 12.5 Examples of characteristics that show discontinuous variation

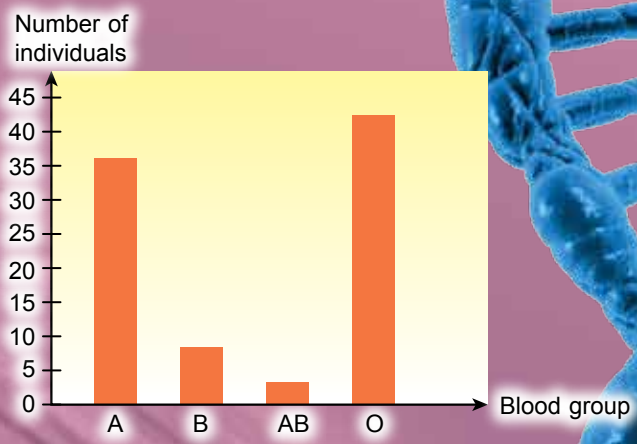


Figure 12.3 Graph of discontinuous variation

Comparison between Continuous and Discontinuous Variation

What are the differences between continuous variation and discontinuous variation (Figure 12.4)?

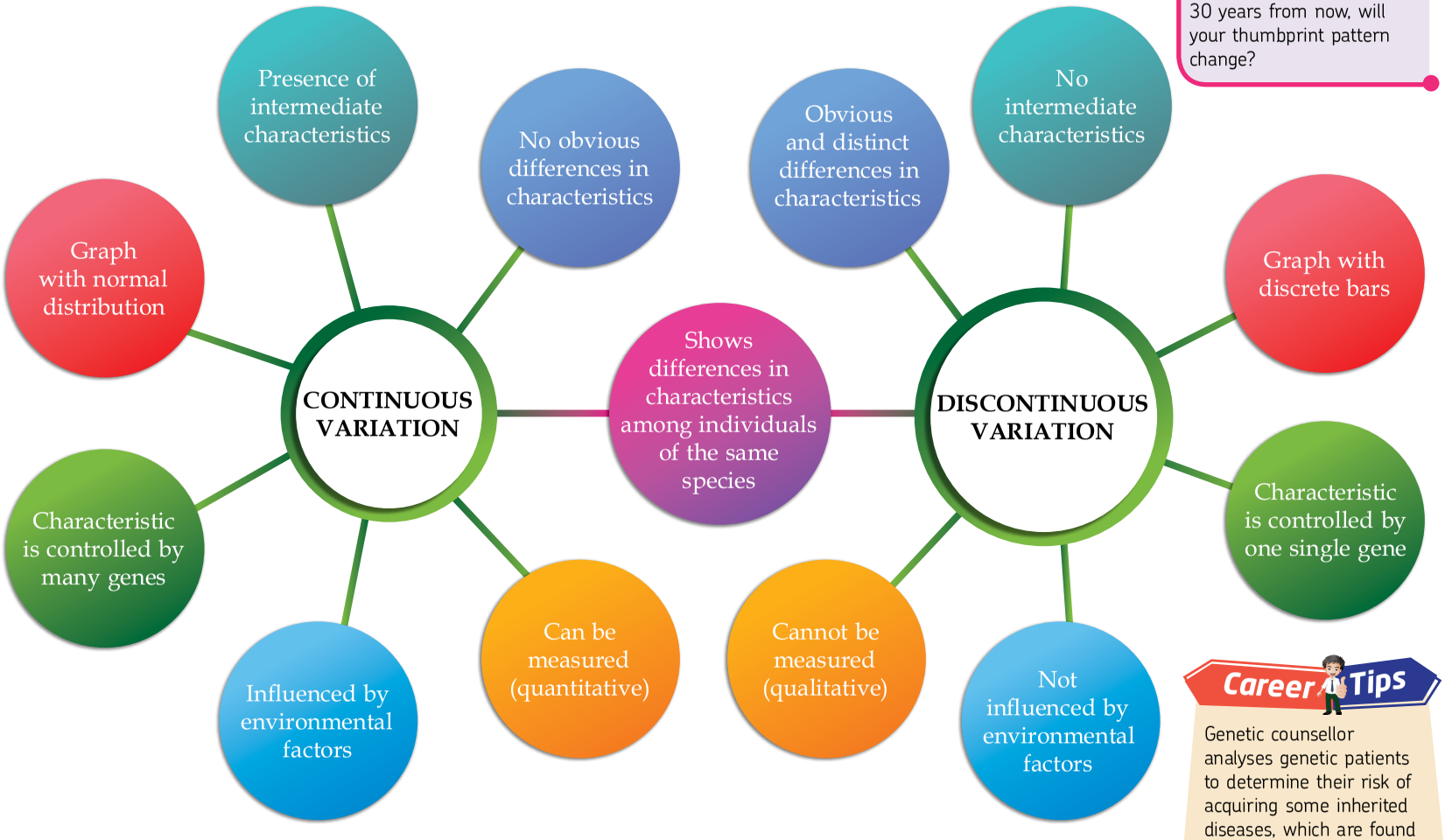


Figure 12.4 Comparison between continuous variation and discontinuous variation

Think Smart

30 years from now, will your thumbprint pattern change?

Career Tips

Genetic counsellor analyses genetic patients to determine their risk of acquiring some inherited diseases, which are found in their genes.

Causes of Variation

Organisms of the same species differ in terms of **morphology, physiology** and **genetics**. What are the causes of variation among these organisms (Figure 12.5)?

Photograph 12.6
Variation on sea shells

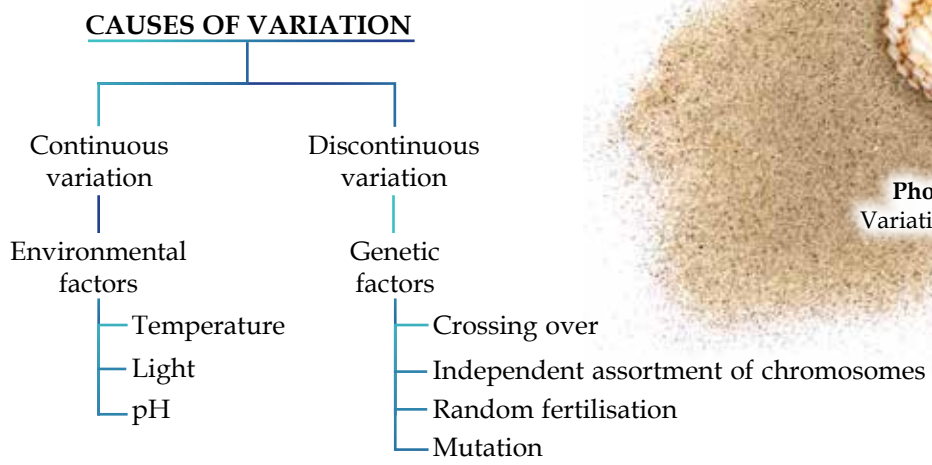


Figure 12.5 Factors that cause continuous variation and discontinuous variation

Genetic Factors

Crossing Over

- Crossing over occurs between non-sister chromatids of homologous chromosomes during prophase I of meiosis.
- Recombination produces new combinations of genes.
- Sister chromatids that separate during anaphase II of meiosis form gametes with different genetic materials at the end of meiosis (Figure 12.6).

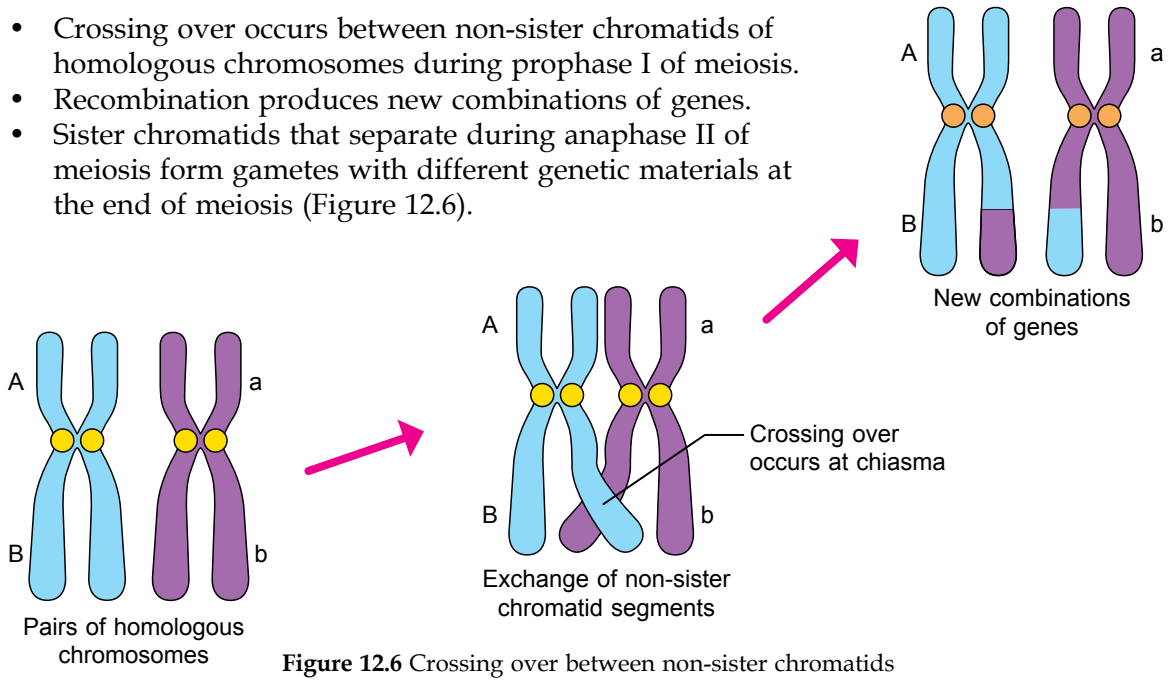


Figure 12.6 Crossing over between non-sister chromatids

Independent Assortment of Chromosomes

- During **metaphase I of meiosis**, a homologous chromosome pair (one **maternal chromosome** and one **paternal chromosome**) is arranged randomly on the equatorial plane of a cell.
- Figure 12.7 shows two probabilities on the arrangement of homologous chromosomes on the **equatorial plane** for each **diploid cell (2n=4)**.
- At the end of meiosis, different gametes will be produced with different combinations of paternal and maternal chromosomes, which results in the genetic contents of each gamete to be different from the others.

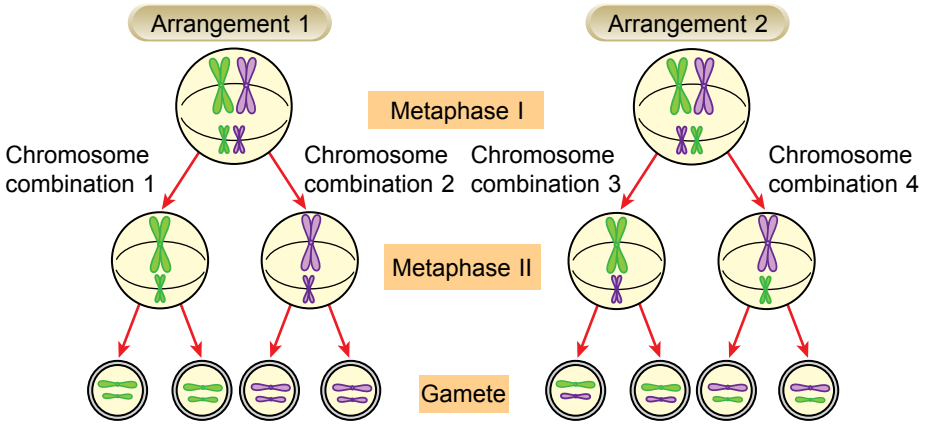


Figure 12.7 Random arrangements of homologous chromosomes during metaphase I

Random fertilisation

- Fertilisation between sperm and secondary oocyte is random.
- Genetic recombination which occurs during crossing over and random arrangement of homologous chromosomes in **meiosis,** produces gametes with different genetic contents from their parents.
- Therefore, a diploid zygote which is produced after fertilisation will have a new genetic combination (Figure 12.8).

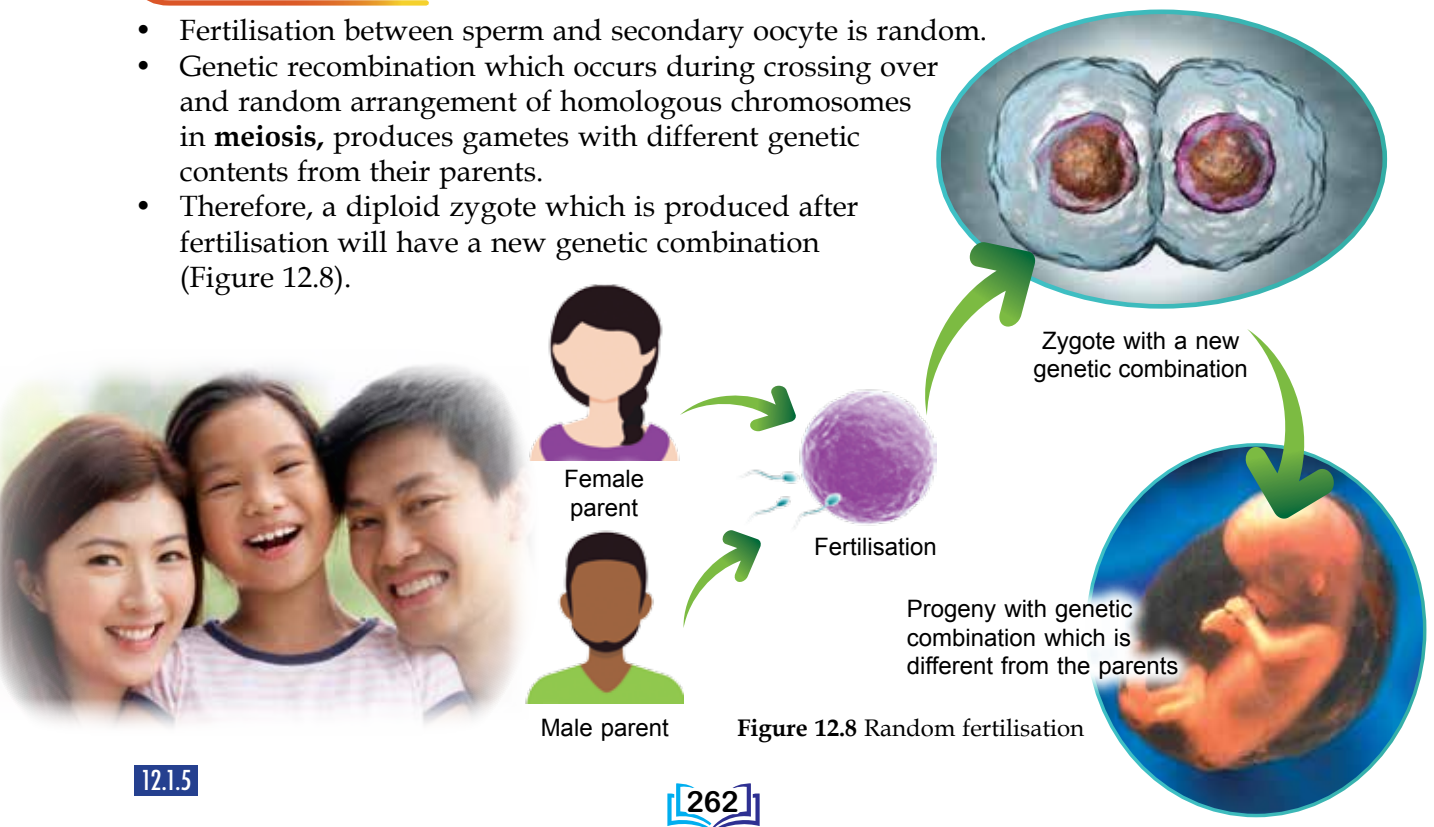


Figure 12.8 Random fertilisation

Mutation

- **Mutation** is a permanent change which occurs spontaneously on genes or chromosomes.
- Mutation creates new genotypes.
- If mutation occurs in the gamete (mutation of germ cell), the characteristics determined by mutated genetic materials can be inherited (Figure 12.9).
- Mutation of the somatic cell can cause variation but the characteristics cannot be inherited by the next generations.

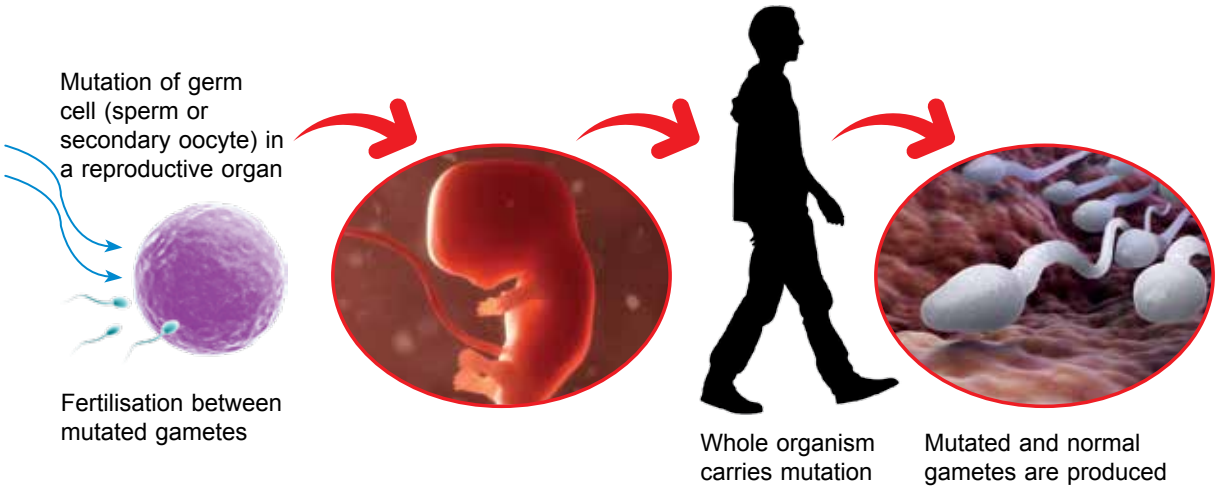


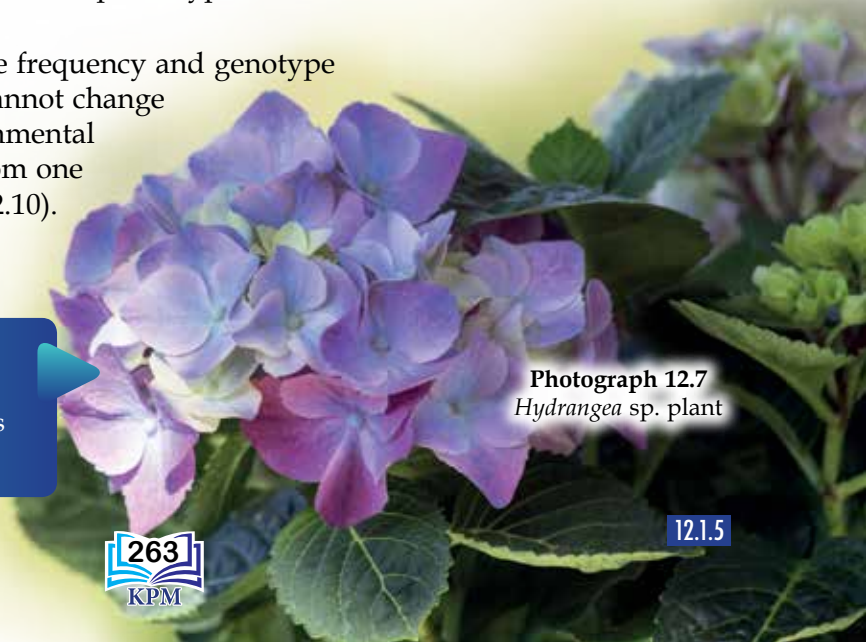
Figure 12.9 Mutation of germ cell

Environmental Factors

Variation caused by environmental factors is known as **environmental variation**. Environmental factors that cause variation include **abiosis factors** such as **temperature, light** and **pH**. In contrast to variation caused by genetics, the effect of environment on variation is small since it only involves phenotypic differences and not genotypic differences.

Environment can change allele frequency and genotype frequency in a population but cannot change the genotype. Therefore, environmental variation cannot be inherited from one generation to the next (Figure 12.10).

Which environmental factors cause *Hydrangea* sp. plant to produce different coloured flowers (Photograph 12.7)?



Photograph 12.7
Hydrangea sp. plant

12.1.5

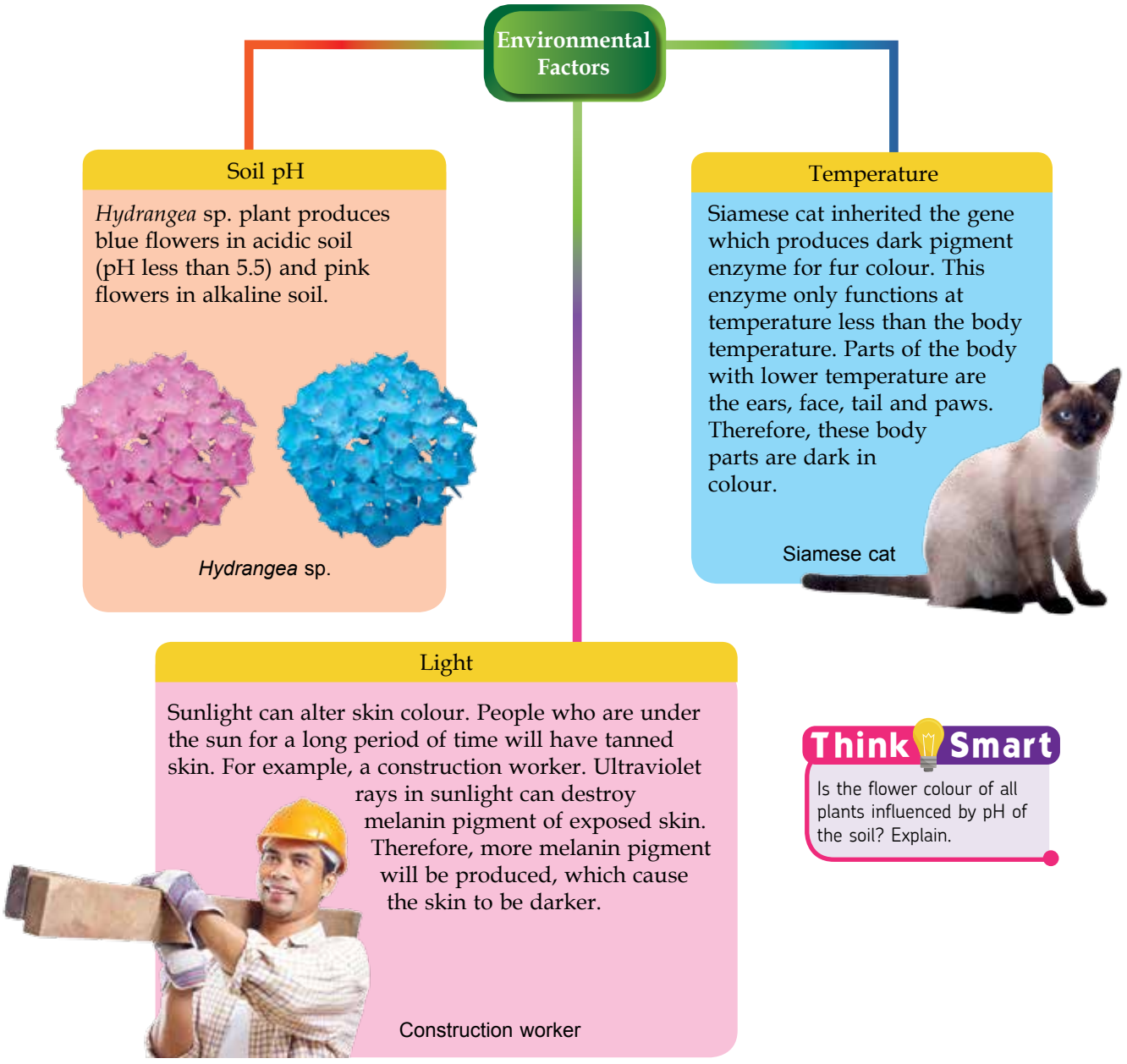


Figure 12.10 Effects of environmental factors on variation

Interactions between Genetic and Environmental Factors

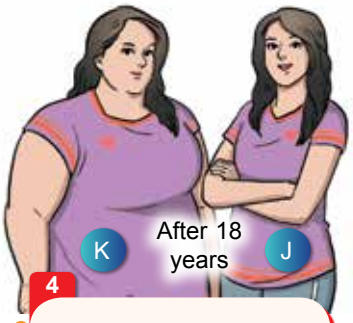
Environmental factors can interact with genetic factors to cause variation, in which the environmental factors determine the phenotypes. Characteristics inherited from parents such as height, intelligence and skin colour are greatly influenced by environmental factors. An example which supports the effect of environmental factors on genetic factors can be observed in identical twins (Figure 12.11).

12.1.5 12.1.6

1 J and K are identical twins. Both have similar genotype for obesity since they originated from the same embryo.

2 J and K were separated since childhood.

3 J likes low fat diet and enjoys physical activities whereas K likes high fat diet and does not like physical activities.



4 K is obese whereas J has an ideal body weight.

Conclusion: Differences in eating habits and environment while growing up produce different phenotypes.

Figure 12.11 Interactions of environmental variations in determining phenotypes of identical twins who possess similar genetic composition

Activity 12.2

21st CENTURY SKILLS

21st CENTURY SKILLS INDIVIDUAL PRESENTATION

Aim

To collect and present information on the effects of environmental factors in determining gender of reptiles and fish

Procedure

1. Work in groups.
2. Study the statement below carefully.

   Gender of embryos of most reptiles and fish depend on environmental factors such as temperature.

3. Present the findings of your group using multimedia presentation.

Formative Practice 12.1

1. How can variation increase the survival of species?
2. Determine the following variations:
   (a) Intelligence
   (b) Presence of dimples
   (c) Type of hair
   (d) Height
   (e) Type of earlobes
3. State **two** causes of variation.
4. Variation occurs because of sexual reproduction

   Explain the above statement.

12.1.6

12.2 Variation in Humans

Relation of Variation to Human Inheritance

As you have learnt in Chapter 11 on Inheritance, human trait is controlled by a pair of alleles, in which an allele can be dominant or recessive. Dominant trait is observed when both dominant alleles are present or when one dominant allele is paired with a recessive allele whereas recessive trait is only shown when both recessive alleles are present. These genetic information causes variation in humans. Table 12.1 and Figure 12.12 show examples of dominant and recessive traits in humans.

Table 12.1 Examples of characteristics and traits in humans

Characteristics	Traits in humans	
	Dominant	Recessive
Height	Tall	Short
Type of hair	Curly hair	Straight hair
Tendency to use hands	Right-handed	Left-handed
Presence of dimples	Presence	Absence
Ability to roll tongue	Can roll tongue	Cannot roll tongue
Type of earlobes	Free earlobes	Attached earlobes

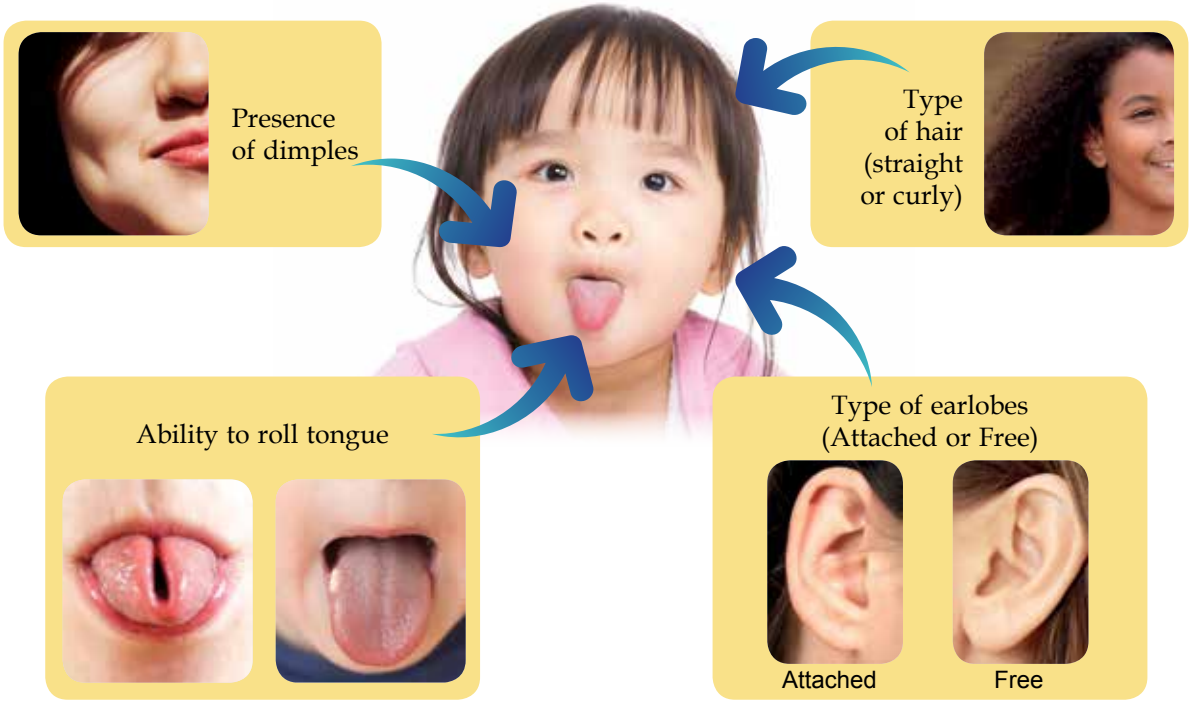


Figure 12.12 Different characteristics in humans

EXPERIMENT 12.1

Continuous and Discontinuous Variation in Humans

Problem statement: Is the height, body weight and fingerprint of each pupil different?

Aim: To study continuous variation and discontinuous variation in humans

Hypothesis: Height, body weight and fingerprint of each pupil is different.

Materials
Graph paper, white papers

Apparatus
Height measuring equipment, weighing machine, ink pad

Procedure

A. Height
1. Measure and record height of each pupil in the class in the results table.
2. Plot a graph of number of pupils against height range.

B. Body weight
1. Weigh and record body weight of each pupil in the class in the results table.
2. Plot a graph of number of pupils against body weight range.

C. Fingerprint
1. Use the fingerprint patterns shown in page 259 for this activity.
2. Place a thumb surface of each pupil on an ink pad, then press the thumb on a piece of white paper.
3. Record the thumbprint pattern of each pupil in the results table.
4. Build a bar chart based on the results obtained.

Results

A. Height

Height range (cm)	<135	135-139	140-144	145-149	150-154	155-159	160-164	165-169	>169
Number of pupils									

B. Body weight

Mass range (kg)	<35	35-39	40-44	45-49	50-54	55-59	60-64	>64
Number of pupils								

C. Fingerprint

Thumbprint pattern	Loop	Arch	Whorl
Number of pupils			

Discussion
1. What are the shapes of the graphs plotted for height and body weight?
2. Give inferences for distribution of height, body weight and thumbprint pattern of the pupils in your class.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

Activity 12.3

Aim
To study the level of human tongue sensitivity towards phenylthiocarbamide (PTC) solution

Hypothesis
PTC taste trait can be classified into specific groups.

Materials
Drinking water, PTC paper

Procedure
1. Rinse your mouth with clean water before starting the activity.
2. Place a piece of PTC paper on your tongue for a few seconds.
3. Record your tongue sensitivity based on the taste of the PTC paper in the results table.
4. Remove the PTC paper from your tongue. Repeat the above steps with other pupils.
5. Build a bar chart based on the results that you obtained.

Phenylthiocarbamide (PTC) is a non-toxic chemical if tasted in small amount.

Results

PTC taste	Bitter	Salty	Sour	Sweet	No taste	Others
Pupil 1						
Pupil 2						
Pupil 3						

Discussion
1. What is the type of variation for PTC taste based on the shape of the graph that is plotted?
2. Is the PTC taste trait dominant or recessive? Explain.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 12.2

1. State the meaning of:
   (a) Inheritance
   (b) Characteristic
2. Give **two** examples of inheritable characteristics in humans.
3. Give **two** examples of traits for eye colour.

12.3 Mutation

Mutation is a spontaneous and random change of genetic material, namely DNA of the cell in an organism. A substance which causes mutation or increases the mutation rate to a dangerous level is called a **mutagen**. Mutation occurs spontaneously in natural conditions. New genetic material produced by mutation is called a **mutant**. A mutant can exist as **mutant gene, mutant cell, mutant organelle** or **mutant individual**.

Types of Mutagen

Mutagen is divided into three types of agents, namely **physical agent**, **chemical agent** and **biological agent** (Figure 12.13).

TYPES OF MUTAGEN

- **Physical agents**
  - Ultraviolet from the sun
  - Ionising rays such as X-ray, alpha ray and beta ray
- **Chemical agents**
  - Carcinogen in cigarette smoke
  - Food preservatives
  - Formaldehyde
  - Benzene
- **Biological agents**
  - Virus
  - Bacteria

Bio Exploration

Mutation that occurs in somatic cells, for example, cells in bone marrow can cause blood cancer.

Figure 12.13 Types of mutagen

Types of Mutations

Gene Mutation

Gene mutation occurs when there is a change in nucleotide base sequence of a gene (Figure 12.14). Gene mutation is also known as **point mutation**. The change alters the genetic code that is used to synthesise amino acid. Therefore, there will be a change in protein structure and this new protein cannot function. Gene mutation occurs by **base substitution**, **base deletion** and **base insertion** (Figure 12.15).

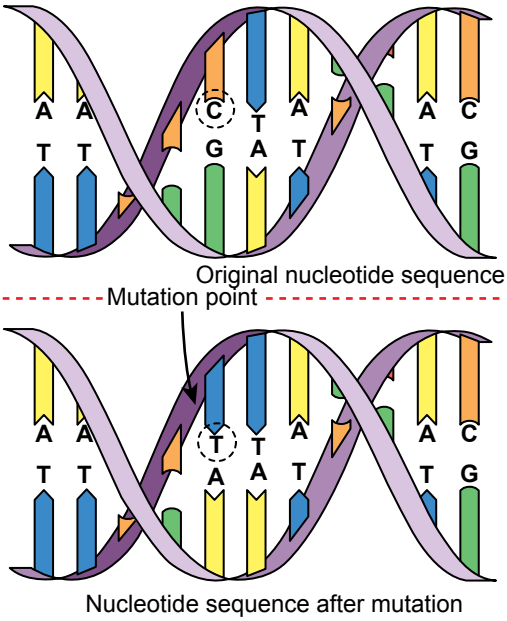


Figure 12.14 Changes of nucleotide in gene

12.3.1 12.3.2 12.3.3

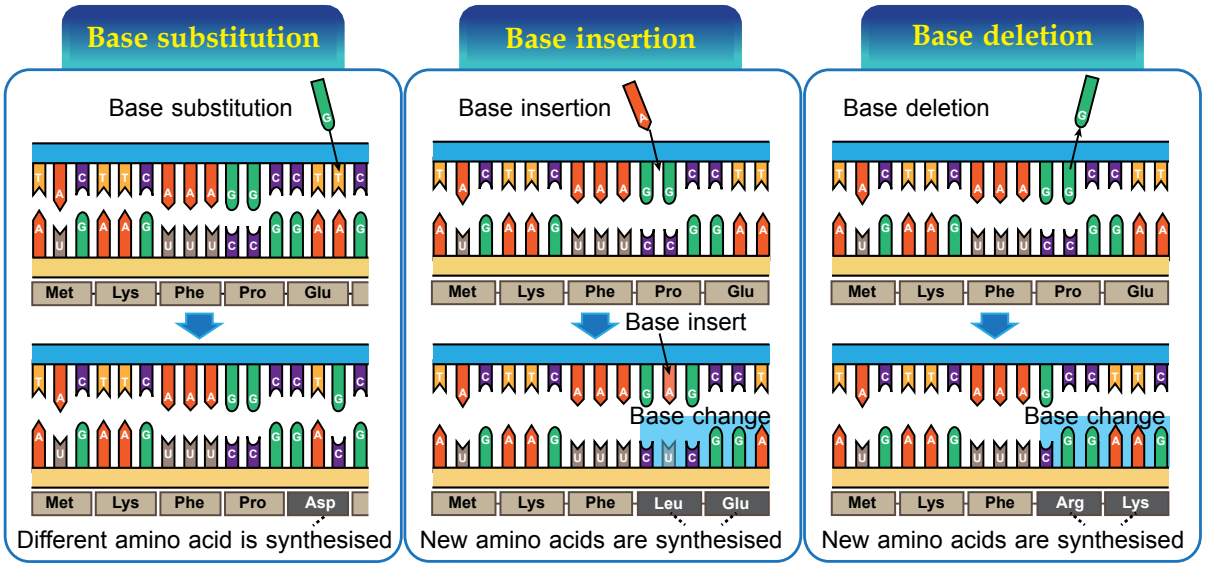


Figure 12.15 Gene mutation

Gene mutation causes genetic diseases such as **thalassemia**, **cystic fibrosis**, **sickle cell anaemia**, **albinisme** and **haemophilia** (Table 12.2).

Table 12.2 Examples of genetic disease

Types of gene mutation	Examples of disease
Base substitution	Sickle cell anaemia
Base insertion	Cystic fibrosis
Base deletion	Thalassemia

Sickle Cell Anaemia

Sickle cell anaemia is caused by a gene responsible for the synthesis of **haemoglobin**. The red blood cells of a patient are in the shape of a crescent. This is because the red blood cells are not properly formed. Some red blood cells are normal whereas the rest are **crescent shape** (Photograph 12.8).

ACTIVITY ZONE

Collect information of haemophilia inheritance in the community. Present your findings in class.

Albinism

An individual who experiences albinism is an **albino**. Albinism is due to the mutation of a gene which is responsible for producing pigments of skin, hair and eyes. Hence, the pigments are not produced in the albino (Photograph 12.9).

Photograph 12.8 Sickle cell anaemia

Photograph 12.9 Albino boy

Chromosomal Mutation

Chromosomal mutation involves changes to **chromosomal structure** or changes to the **chromosomal number**. Chromosomal mutation can change the characteristics of an organism.

Changes in chromosomal structure involve changes to the gene sequence in a chromosome. The structural change causes abnormality to the chromosome, which is known as **chromosomal aberration**. Types of chromosomal aberration include **deletion, duplication, inversion** and **translocation** (Figure 12.16).

Bio Exploration

The risk of mutation in a foetus increases as the age of the mother increases.

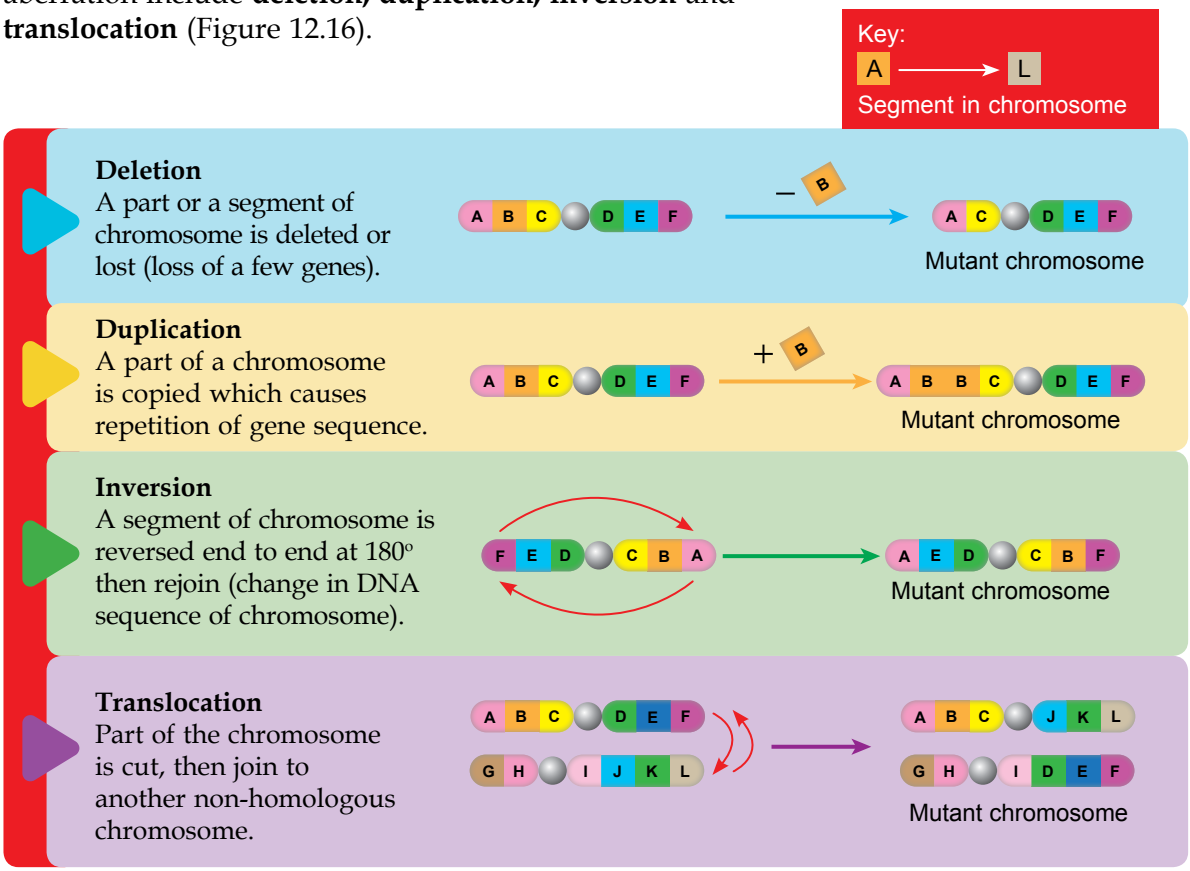


Figure 12.16 Chromosomal mutation

A change in chromosomal number causes a diploid organism to lose one or more chromosomes, or gain one or more chromosomes. The change occurs when homologous chromosomes fail to separate during **anaphase I in meiosis** or sister-chromatids fail to separate during **anaphase II in meiosis**. This is probably because the normal **spindle fibres** fail to form during meiosis. The phenomenon is known as **nondisjunction** and it causes abnormality in the number of chromosomes and in a gamete. The gamete may lose one or more chromosomes or gain one or more chromosomes (Figure 12.17).

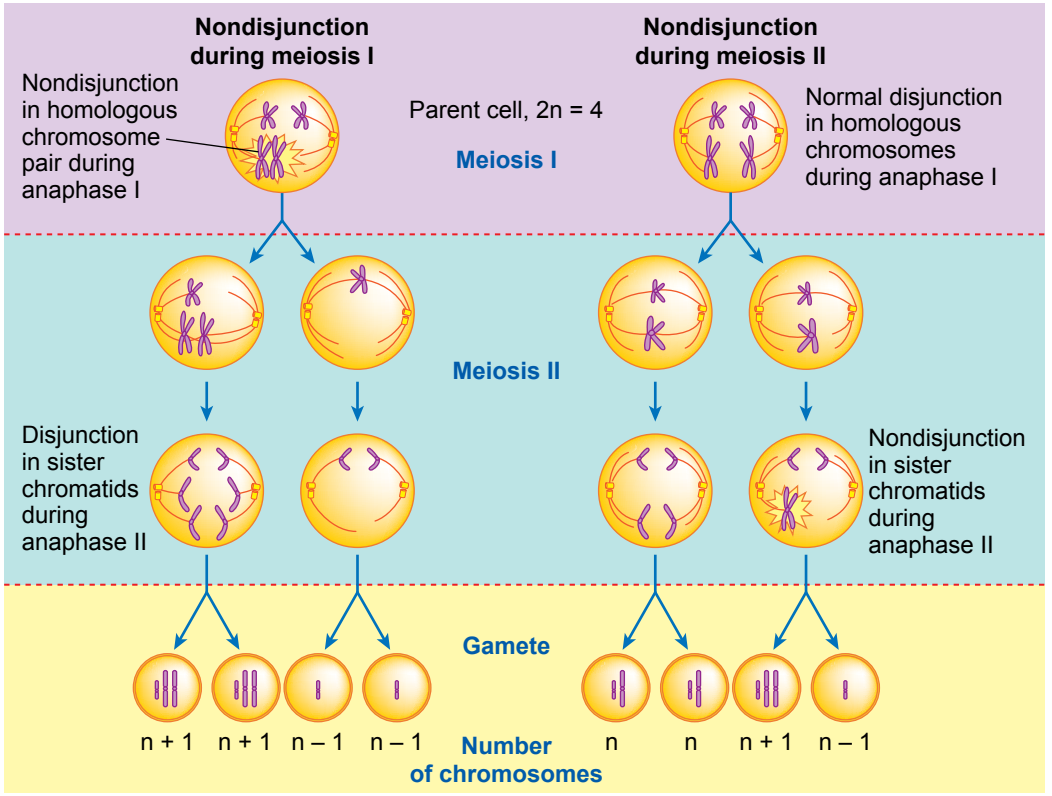


Figure 12.17 Nondisjunctions in chromosomes during meiosis

Abnormality in the number of chromosomes can be due to nondisjunction during **spermatogenesis** or oogenesis. Fertilisation that involves abnormal gametes will produce a zygote that develops into an individual with abnormal characteristics. The individual experiences change in phenotype (Figure 12.18).

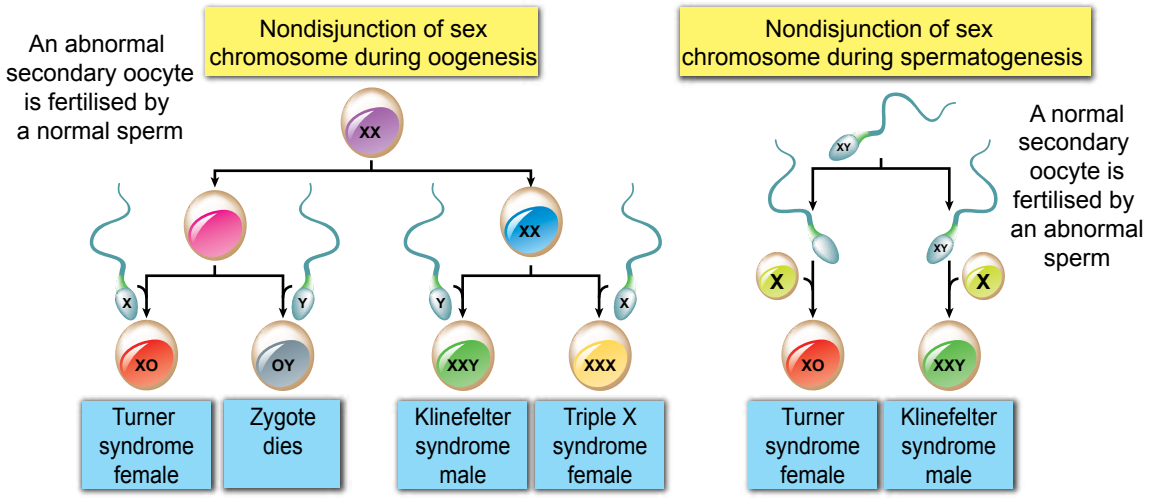
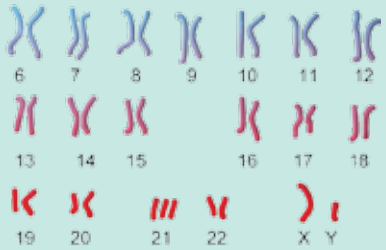


Figure 12.18 Diseases caused by mutation of chromosomal number

Table 12.3 Characteristics of diseases caused by chromosome mutation

Diseases	Chromosome number	Characteristics of diseases
Abnormalities in autosomes		
Down Syndrome	(2n + 1) = 47 Has three number 21 chromosomes  **Figure 12.19** Caryotype	An individual (male or female) has slant eyes, flat nose, protruding tongue, broad forehead and is usually mentally retarded (Photograph 12.10).  **Photograph 12.10** A Down syndrome individual
Cri du chat syndrome	The structure of chromosome changes due to a partial deletion on the short arm of chromosome number 5.	The cry of affected infants is similar to that of a meowing kitten. Affected individual shows delayed development with mental and physical retardation. Most patients die during childhood.
Abnormalities in sex chromosomes		
Klinefelter Syndrome	(2n + 1) = 47 44 + XXY  **Photograph 12.11** Klinefelter syndrome individual	A sterile man with small testes that fail to produce sperms. Possesses voice and chest similar to those of a woman. Has long legs and hands.
Jacob Syndrome	(2n + 1) = 47 44 + XYY  **Photograph 12.12** A Jacob syndrome individual	Male who is taller than normal and has problem with pimples on his face. Slow in acquiring speech and has learning disability. Possesses weak muscles (hypotonia).
Turner Syndrome	(2n - 1) = 45 44 + XO  **Photograph 12.13** A Turner syndrome individual	Sterile female with lack of secondary female characteristics, undeveloped breasts and ovaries. Weblike neck and low IQ.

Mutation of Somatic Cells and Gametes

Mutation can occur in somatic cells and gametes to produce variation in a population. What are the differences between mutation in somatic cells and gametes (Table 12.4)?

Table 12.4 Differences between mutations of somatic cells and gametes

Mutation in somatic cells	Mutation in gametes
Involves somatic cells such as skin cell and eye cell	Involves germ cell that produces gamete (secondary oocyte or sperm)
Cannot be inherited by the next generation	Can be inherited by the next generation
Disease is present only in the individual with the mutation	Disease is present in the individual with the mutation and is also inherited by his/her descendants
Example: Disease related to nervous system	Example: All inherited diseases such as thalassemia

Activity 12.4

21st CENTURY SKILLS

21st CENTURY SKILLS INDIVIDUAL PRESENTATION

Aim

To carry out a study and present the impact of nuclear accidents and Vietnam War on plants, animals and humans

Procedure

1. Work in groups.
2. Scan the QR codes below and find information on:
   (a) The use of agent orange during the Vietnam War
   (b) Nuclear accidents at Fukushima and Chernobyl

Info **Vietnam War**
bukutekskssm.my/Biologi/T5/Ms274a

Info **Fukushima nuclear accident**
bukutekskssm.my/Biologi/T5/Ms274b

Info **Chernobyl nuclear accident**
bukutekskssm.my/Biologi/T5/Ms274c

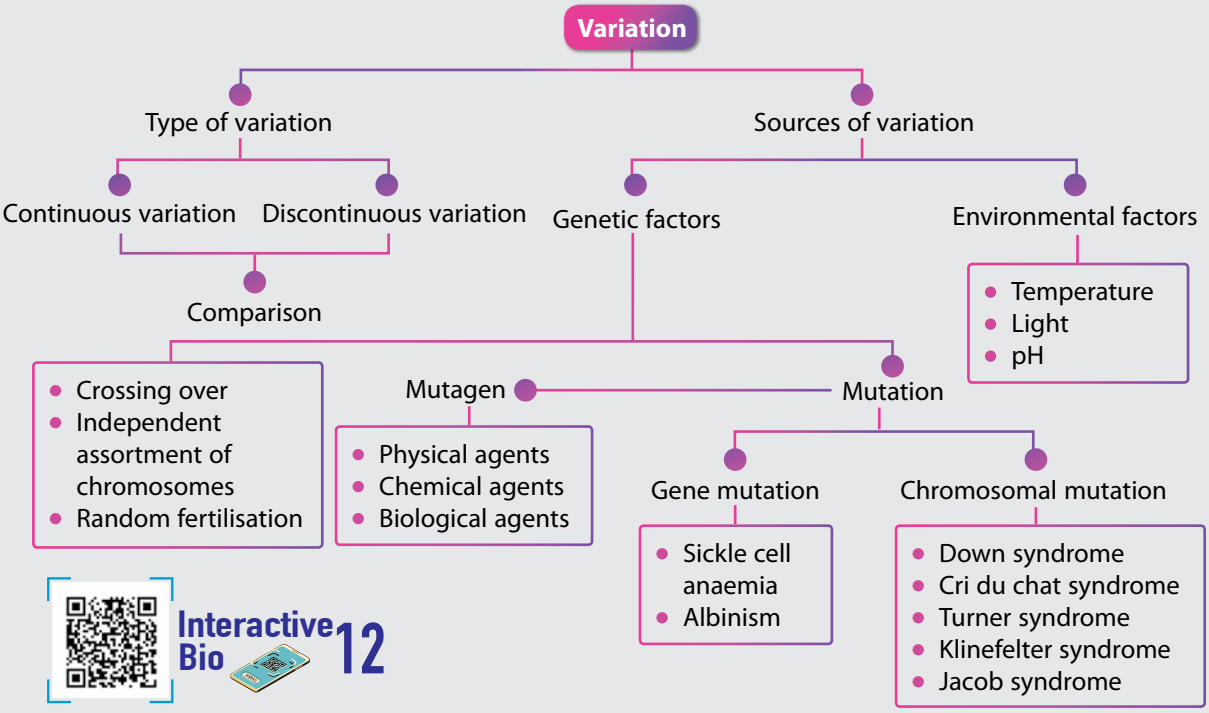
3. Discuss the impacts of the above events on plants, animals and humans.
4. Present the findings of your group.

Formative Practice 12.3

1. State the differences between gene mutation and chromosomal mutation.
2. Explain briefly the following statement by giving suitable examples:

Food can be a source of mutation.

Memory Flashback



Interactive Bio 12

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of variation		
The importance of variation for survival of species		
Types of variation, namely continuous variation and discontinuous variation		
Comparison between continuous variation and discontinuous variation		
Causes of variation		
Relationship between types of variation and human inheritance		
Meaning of mutagen, mutation and mutant		
Types of mutagen and mutation		
Relationship between somatic cell mutation and gamete mutation with variation		

Summative Practice 12

1. Tables 1.1 and 1.2 show data that were collected for two different characteristics from 35 pupils in Form 5 Bunga Raya.

Table 1.1 Body mass of pupils in Form 5 Bunga Raya

Body mass (kg)	40-44	45-49	50-54	55-59	60-64
Number of pupils	5	7	9	8	6

Table 1.2 Types of earlobes of pupils in Form 5 Bunga Raya

Earlobes	Attached	Free
Number of pupils	6	29

(a) (i) State the types of variation for body mass and types of earlobes.

(ii) State **two** differences between body mass variation and types of earlobes variation.

(b) Figure 1.1 shows a karyotype of an individual who has a genetic disease caused by mutation.

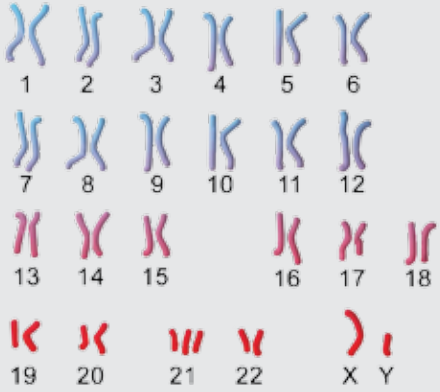


Figure 1.1

(i) State the disease shown in Figure 1.1.

(ii) Which type of mutation causes the disease stated in 1(b)(i)?

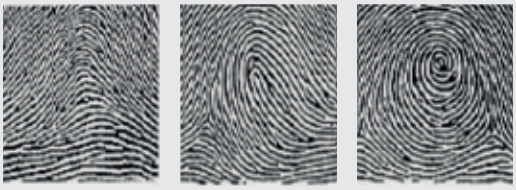
(iii) Explain how the type of mutation in 1(b)(ii) causes the disease.

(c) The statement below describes trees of the same species planted in two different plots, X and Y on a farm.

Plot of land X: trees grown from the same tissue culture
Plot of land Y: trees planted from seeds

The plantation was infected and all trees in plot X were killed whereas only part of the plants in plot Y died of the infection. Explain why all the plants in plot X were killed.

2. (a) Figure 2.1 shows patterns of a few thumbprints.



Arch Loop Whorl

Figure 2.1

Identify the types of variations for the thumbprint pattern and discuss the factors that cause these variations.

(b) (i) State the difference between gene mutation and chromosomal mutation.

(ii) Figure 2.2 shows four types of chromosomal mutations K, L, M and N. Based on Figure 2.2, explain the mutation types of K, L, M and N.

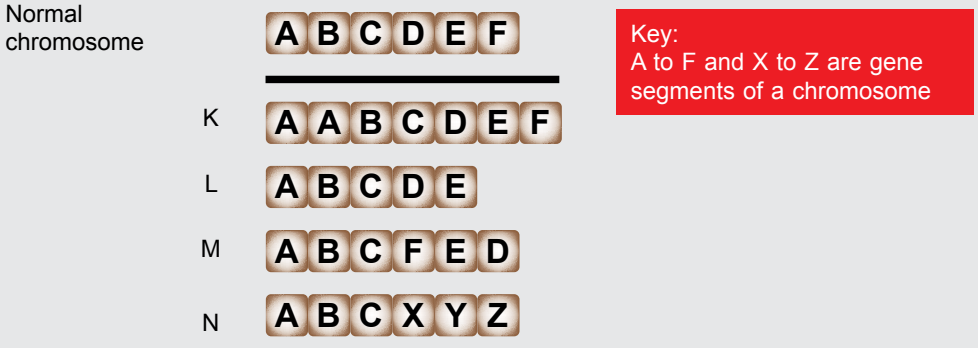


Figure 2.2

21st Century Mind

3. Sickle cell anaemia is an inherited disease. The disease is caused by a gene mutation in which a DNA base substitution results in the replacement of a glutamic acid (a type of asid amino) by a valina (another type of amino acid) in haemoglobin. This causes the patient to possess haemoglobin S, HbS which causes the red blood cell to look like a sickle or crescent instead of the normal biconcave shape. The sickled cells cause chronic anaemia. Africa is a continent endemic for malaria in which a proportion of the population carries the sickle cell trait. As a scientist, discuss the relationship between sickle cell and malaria in Africa.

Chapter 13

Genetic Technology

Chapter Exploration

- Genetic Engineering
- Biotechnology

Learning Standards

Do You Know?

- What is the meaning of genetic engineering?
- What are the biotechnology applications used to solve problems faced by humans?

Genetic Engineering

Genetic knowledge gained through Mendel's inheritance experiments and molecular structure of DNA enables scientists worldwide to actively perform researches in genetics to improve the quality of humans' life.

Beneficial genes can be transferred from animals or plants and inserted into genome of microorganisms such as bacteria to produce useful products that are useful to humans. Through gene manipulation processes, new genotypes can be produced which ultimately lead to production of new genotypes.

Although genetic engineering brings a lot of benefits to humans, it also creates many ethical and moral issues. Experts in genetically modified food (GMF) committees have to monitor abuses or malpractices in genetic engineering and the decisions made must be guided by the existing code of ethics.

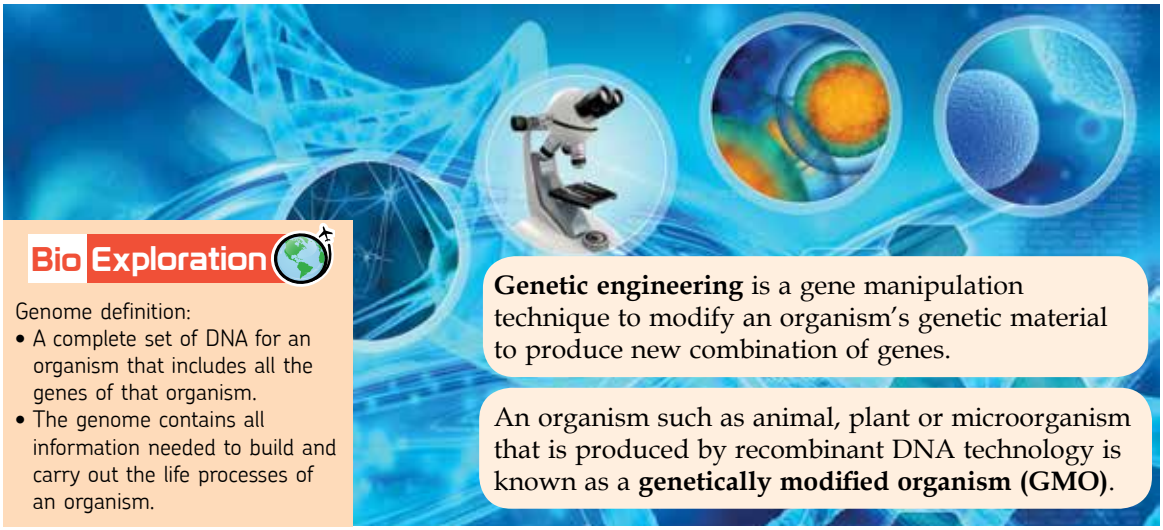
Keywords

- Genetic engineering
- Genetically modified organisms (GMO)
- Genetically modified food (GMF)
- Biotechnology
- Gene therapy
- DNA profiling
- Plasmid
- Cloning vector

13.1 Genetic Engineering

Genetic Engineering and Genetically Modified Organism (GMO)

Have you ever heard of genetic engineering? What are the purposes of performing this technique in an organism?



Bio Exploration

Genome definition:
- A complete set of DNA for an organism that includes all the genes of that organism.
- The genome contains all information needed to build and carry out the life processes of an organism.

Genetic engineering is a gene manipulation technique to modify an organism's genetic material to produce new combination of genes.

An organism such as animal, plant or microorganism that is produced by recombinant DNA technology is known as a **genetically modified organism (GMO)**.

Genetic engineering involves the transfer of a DNA segment from one organism to another by DNA recombinant technology. By using the techniques and procedures in the recombinant technology, biologists can recombine the DNA or **genome** (a complete set of DNA) of an organism.

Genetically Modified Organism (GMO)

Genetically modified organisms (GMOs) are organisms that contain recombinant DNA. Recombinant DNA technology enables production of new gene combinations. An organism that contains recombinant DNA is known as a **transgenic organism** (Photograph 13.1)

This genetically modified cow produces milk which does not contain β-lactoglobulin, a type of protein that causes allergy among some children.

This genetically modified goat possesses the human gene which codes for a blood clotting factor. This blood coagulation factor is found in the goat's milk and can be purified and used to treat haemophilic patients.

Photograph 13.1 Examples of genetically modified organisms (GMO)

13.1.1 13.1.2

Genetically Modified Food (GMF)

Recombinant DNA technology has successfully produced many beneficial varieties of crops (paddy, oil palm, pineapple, corn and soya bean) and livestock (salmon, cattle and goat) (Figure 13.1). **Genetically modified food (GMF)** possesses DNA from other species of plant or animal. Consumption of GMF by humans may cause health implications which are still unknown.

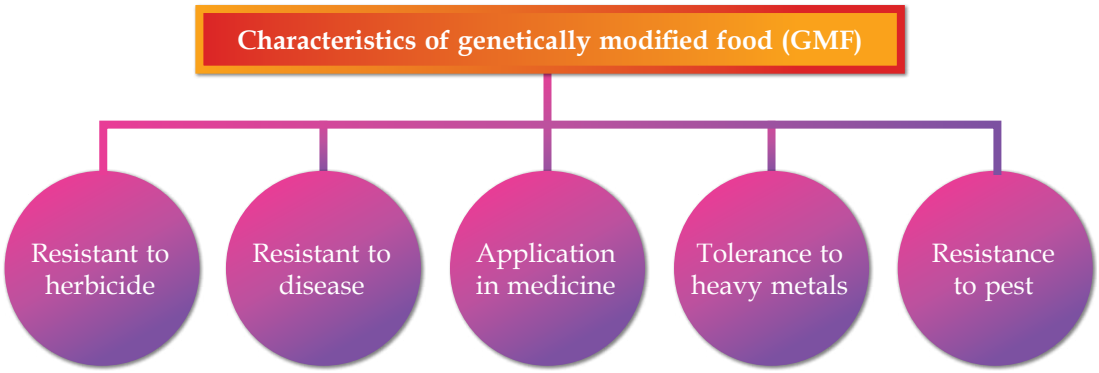
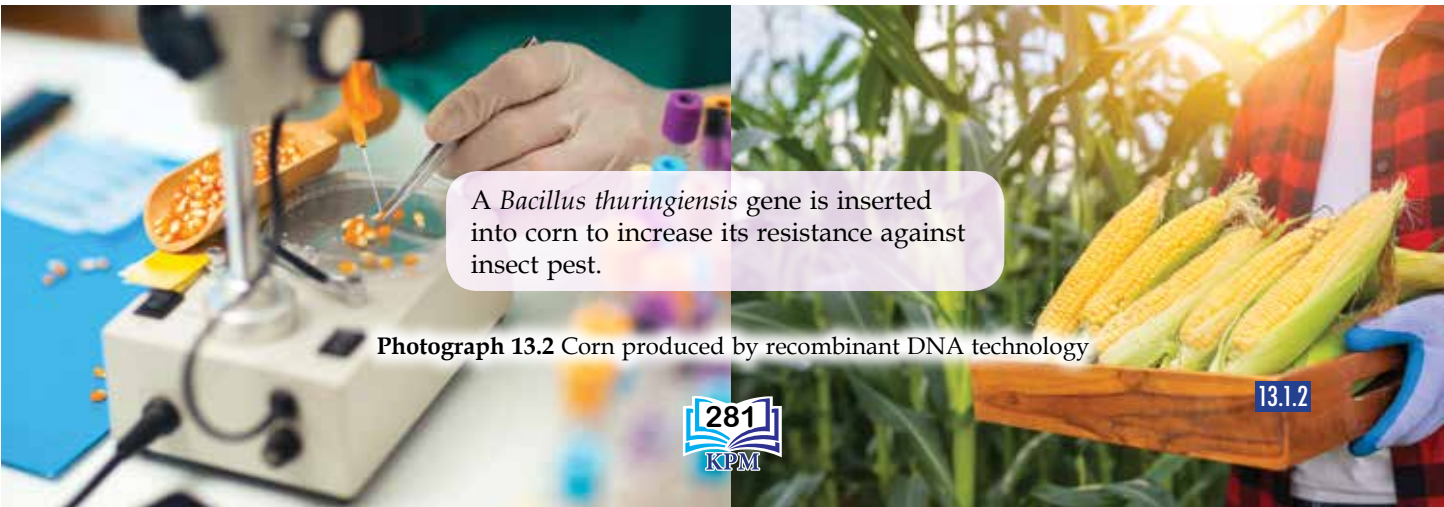


Figure 13.1 Characteristics of genetically modified food (GMF)

Table 13.1 Advantages and disadvantages of GMF

Advantages of GMF	Disadvantages of GMF
• Overcome worldwide food shortage by producing high quality transgenic crops and livestock • Reduce cost of food production • Increase nutritional value of crops • Reduce problems of crops related to pests • Reduce usage of pesticides • Increase in production reduces price of food, thus increase food availability	• Endangered natural species • There is a slight possibility that the foreign gene in GMF may be transferred to humans, for example, antibiotic-resistance gene • May have adverse effects on human health and genetic material



Photograph 13.2 Corn produced by recombinant DNA technology

Photograph 13.3 Normal salmon and Super Salmon

Super Salmon is a genetically modified fish which is approved by the Food and Drug Administration (FDA) as a safe food for consumption in United States of America and Canada. It is modified by inserting a growth hormone gene from a Chinook salmon into the genome of an Atlantic salmon. Hence, a Super Salmon is created which grows at a faster rate and can be produced throughout the year.

Potato is an important crop to people who live in cold climates. It is very sensitive to low temperature and frost. A gene from *Arabidopsis* sp. plant, which enables the plant to tolerate freezing condition is inserted into the potato genome to create a genetically modified potato that can grow well in cold climates.

Photograph 13.4 Effect of frost on potatoes

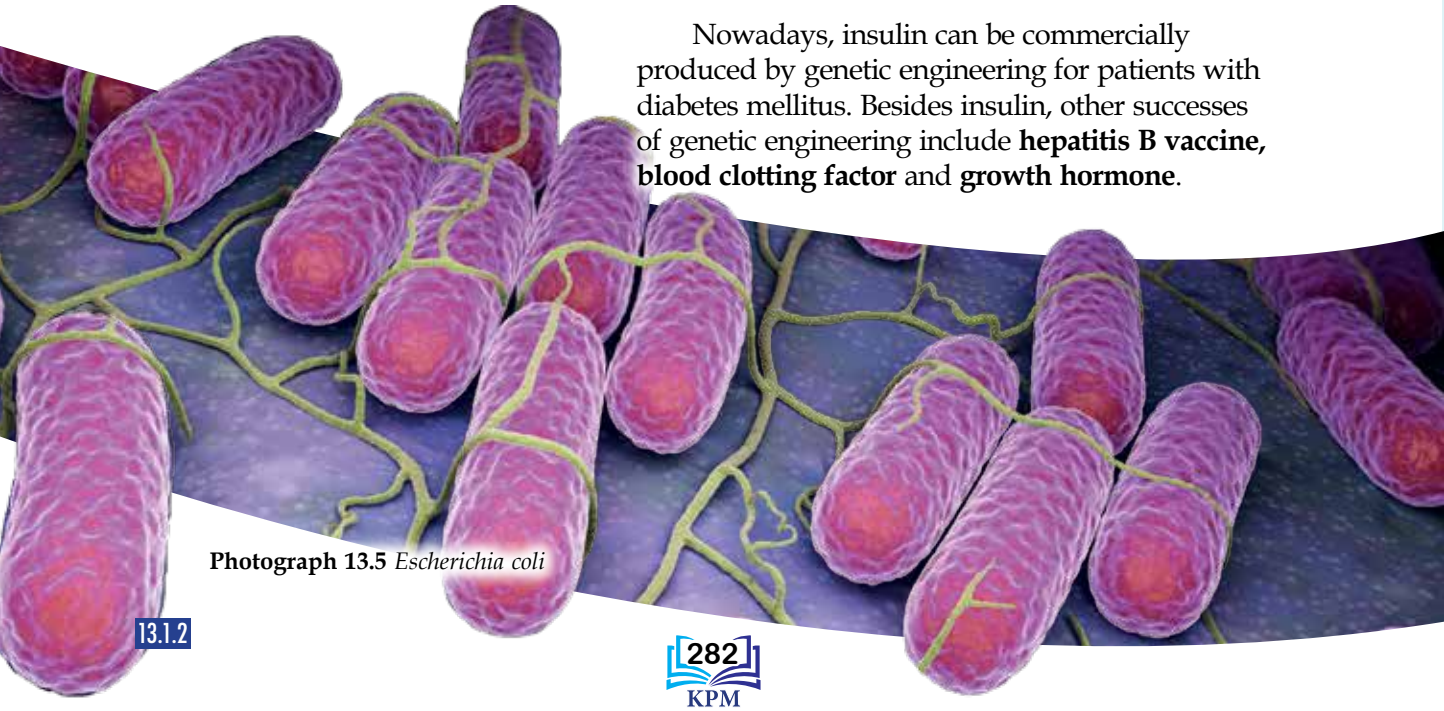
Insulin

You have already learnt the concept of homeostasis in regulating blood glucose level. **Insulin** is an important **hormone** which controls blood glucose level. In the older days, insulin was extracted from the pancreases of cattle or pigs to treat diabetes mellitus patients.

Bio Exploration

Escherichia coli can be used to synthesis insulin (Photograph 13.5).

Nowadays, insulin can be commercially produced by genetic engineering for patients with diabetes mellitus. Besides insulin, other successes of genetic engineering include **hepatitis B vaccine, blood clotting factor** and **growth hormone**.



Photograph 13.5 *Escherichia coli*

13.1.2

Figure 13.2 shows how the human insulin gene is transferred to a bacterium by genetic engineering to produce insulin.

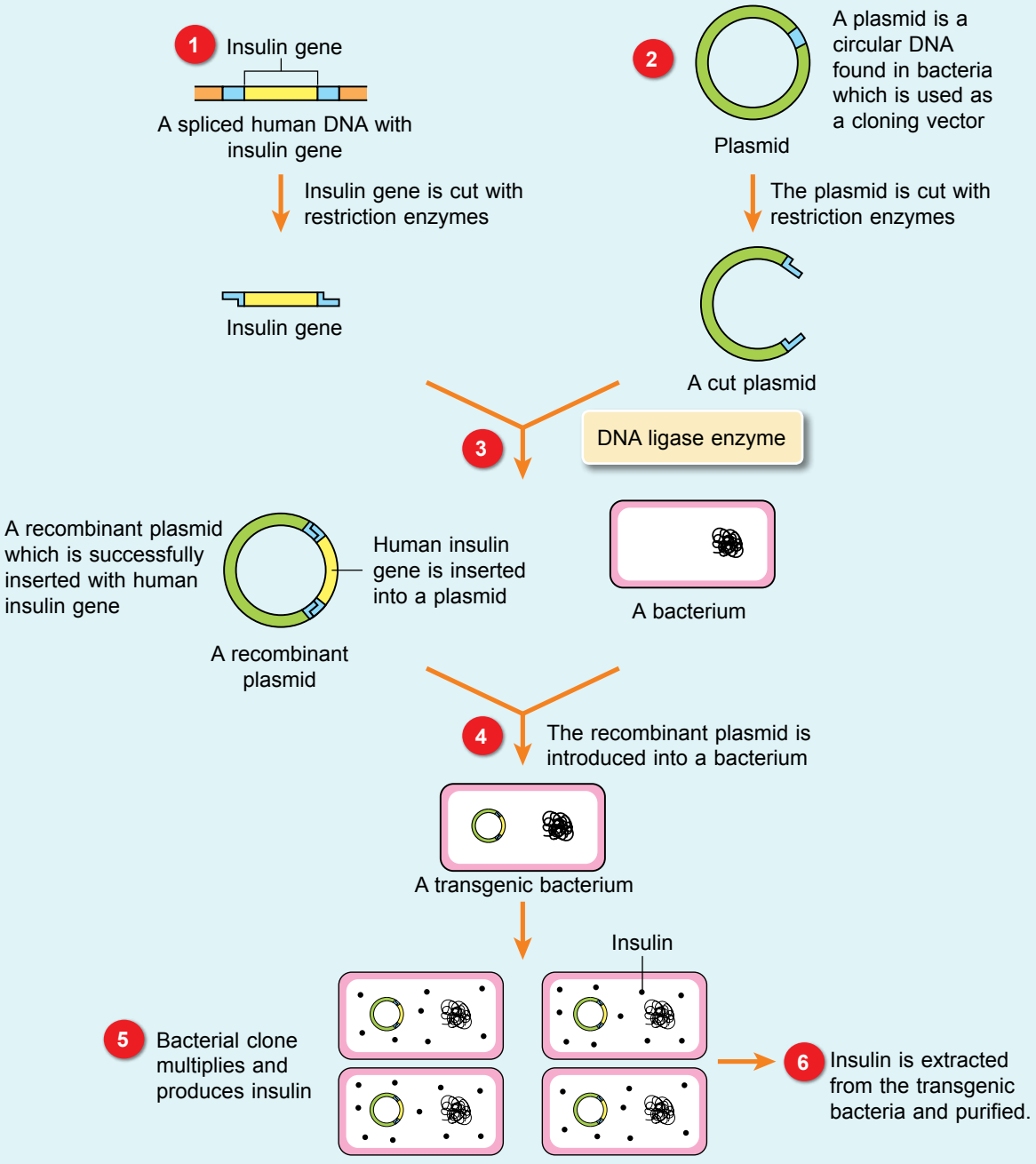


Figure 13.2 Production of insulin by genetic engineering technique

There are many examples of genetically modified organisms (GMOs) and genetically modified food (GMF) which have been produced by genetic engineering. Can you make a list of other GMOs and GMF? What are the advantages and disadvantages of producing these GMOs and GMF to humans and the environment? Carry out Activity 13.1 to obtain further information on the issue.

13.1.2

Activity 13.1

21st CENTURY SKILLS

21st CENTURY SKILLS DEBATE

Aim

To debate on the advantages and disadvantages of producing GMO and GMF

Procedure

1. Work in two groups.
2. Gather recent information on GMO and GMF.
3. Appoint a representative from each group. The representative either leads the affirmative team or the opposing team.
   (a) **Affirmative team:** GMO and GMF bring advantages
   (b) **Opposing team:** GMO and GMF bring disadvantages
4. Prepare your arguments on the debate entitled 'Advantages and Disadvantages of Producing GMO and GMF'.
5. Debate on the above topic.

Formative Practice 13.1

1. What is the meaning of genetic engineering?
2. What is a transgenic organism?
3. State **one** issue on genetically modified food (GMF) that is often debated.

13.2 Biotechnology

Definition of Biotechnology

Biotechnology is a field which utilises technology or method to manipulate organisms for the production of biological products.

Biotechnology aims to improve the quality of livestock and crops as well as to develop the application of microorganisms for specific purposes. Since biotechnology involves various disciplines of science, therefore each discipline that involves the use of living organisms for a specific purpose is given a specific colour code as shown in Figure 13.3. Although ten biotechnology activities are identified, the main ones are the green, white, yellow and blue biotechnology activities. Do you know the meaning of each biotechnology colour?

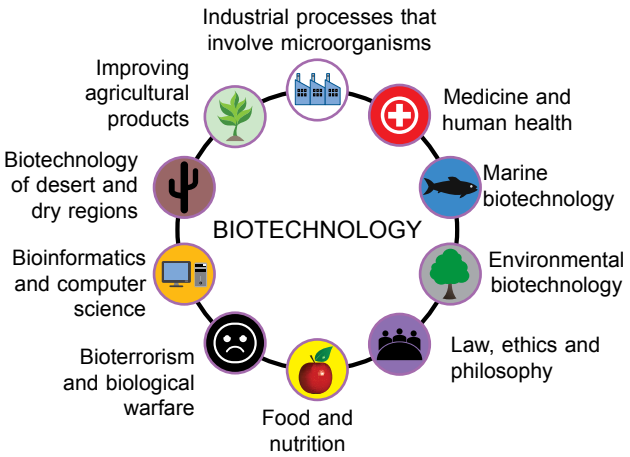


Figure 13.3
Types of biotechnology activities based on colours

13.1.2 13.2.1

Activity 13.2

21st CENTURY SKILLS GALLERY WALK

Aim

To search and present information on classification of the fields in biotechnology

Procedure

1. Work in groups.
2. Gather information on classification of the fields in biotechnology.
3. Present your information in the form of a poster.
4. Carry out Gallery Walk to observe presentations from the other groups.

Activity 13.3

Aim

To visit and gather information on yellow biotechnology at FRIM, MPOC, MARDI, MRB and universities to collect information related to yellow biotechnology

Procedure

1. Work in groups.
2. Teacher organises trips for pupils to one of the following organisations:
   (a) FRIM
   (b) MPOC
   (c) MARDI
   (d) MRB
3. As a group, gather information related to yellow biotechnology through interviews or from pamphlets.
4. Write a report based on the visit.

Applications of Biotechnology in Life

Gene Therapy

Gene therapy is used to treat or prevent genetic diseases. In gene therapy, a normal gene is inserted into the patient to replace the abnormal gene (Figure 13.4). The diseases that can be cured by gene therapy are **cystic fibrosis**, **muscular dystrophy** and a few types of **cancer**.

History Corner

The first successful gene therapy was performed in 1990 on Ashanti DeSilva, a patient with ADA-SCID, a genetic disease that interfered with her body immune system.

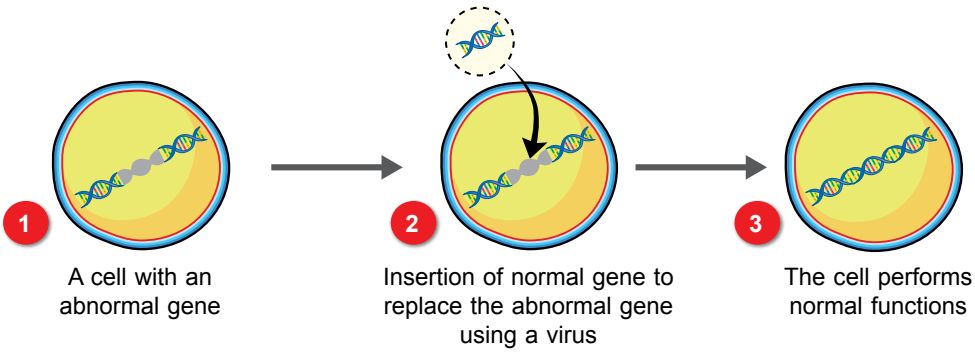


Figure 13.4 Basic steps in gene therapy

13.2.1 13.2.2

Activity 13.4

21st CENTURY SKILLS

21st CENTURY SKILLS
INDIVIDUAL PRESENTATION

Aim

To discuss a gene therapy technology called Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)

Procedure

1. Work in groups.
2. Read the passage below.

> Active researches have been ongoing using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology to edit genome during gene therapy.

3. Gather information on CRISPR technology.
4. Discuss the information that you have gathered and present it in your class using multimedia presentation.

DNA Profiling

DNA profiling is a technique used in forensic to identify individuals, based on their DNA. This is due to the fact that an individual's DNA is unique, except between identical twins. A human DNA set is different from animals. An individual can be identified based on the DNA obtained from his/her blood, semen (for male) or skin. Figure 13.5 shows a few applications of DNA profiling. Figure 13.6 shows the steps used in DNA profiling technique.

- Identify criminal
- Settle paternity and maternity dispute
- Identify genetic disease
- Determine suitability of organ donour and recipient

Figure 13.5 Applications of DNA profiling

Photograph 13.6 Sir Alec Jeffreys

History Corner

DNA profiling technique was invented by Sir Alec Jeffreys in Leicester University in 1985. He was awarded for his achievement the Copley Medal, the oldest award before the Nobel Prize was introduced.

Bio with LAWS

DNA profiling can be used as a strong evidence in a criminal case if:

- the biological sample is obtained and processed correctly and consensusly
- the forensic scientist tests the sample and analyses it meticulously in a transparent manner
- the test results are interpreted precisely
- the jury and judge obtain an accurate report

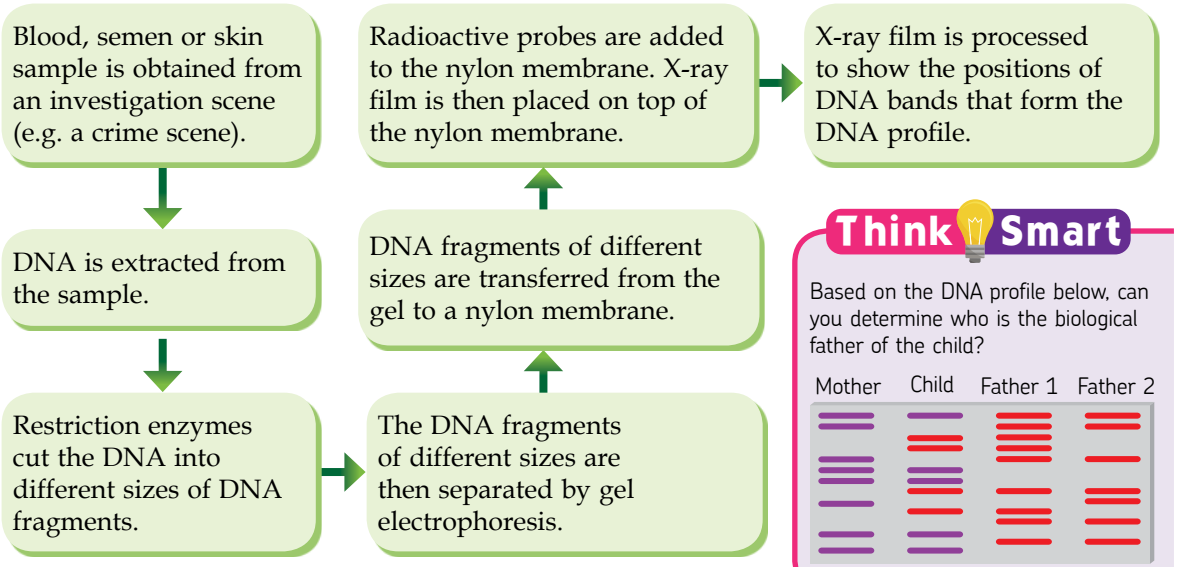


Figure 13.6 Steps used in DNA profiling

Production of Insect Tolerant Plants

Farming cotton breed with high yield and resistant to pests such as **Bt cotton** (Table 13.2) in cotton farms has reduced the use of pesticides. The Bt crop is injected with genes from *Bacillus thuringiensis* (Bt), a type of soil bacteria that secretes toxins (Figure 13.7). This effort has saved cost by reducing the use of pesticides and also increases cotton yield. Besides cotton, other Bt crops are corn and brinjal.

Table 13.2 Comparison between normal crop and GMO crop

Normal crop	GMO crop
 Normal cotton	 Bt cotton
 Normal corn	 Bt corn

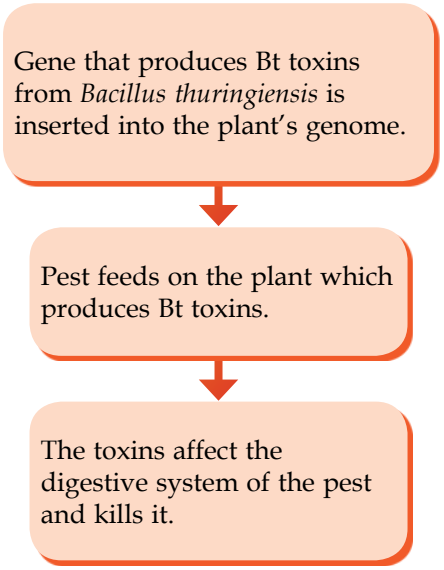


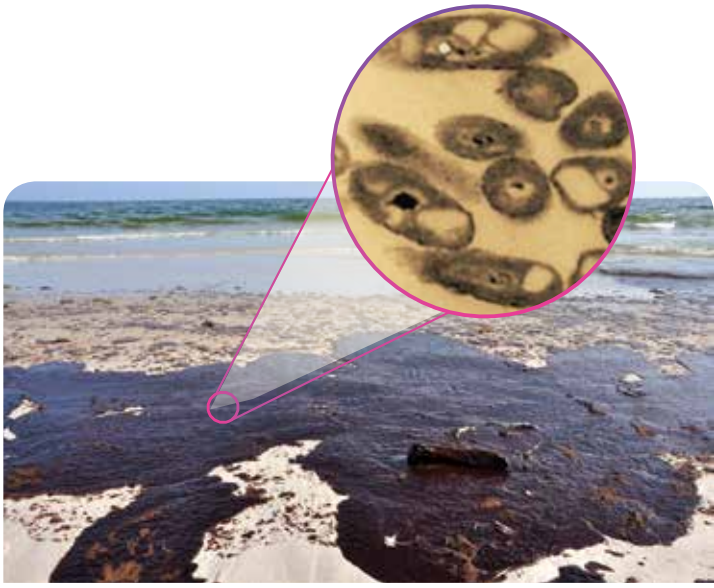
Figure 13.7 Effect of Bt crops on pest

13.2.2

Cleaning of Oil Spills

Bioremediation is a method which uses bacteria to clean up environmental pollutants. It is effective to treat oil spillage in the ocean. Most molecules in crude oil and purified oil products can be degraded by bacteria.

For example, *Alcanivorax borkumensis* (Photograph 13.7), a type of bacteria that depends on oil for its source of energy is widely used to treat oil spills. Can you state the advantages of this bioremediation?



Photograph 13.7 *Alcanivorax borkumensis* is used to treat oil contamination

ACTIVITY ZONE

Collect information of other biotechnology applications such as the production of microbial metabolites, nanobiotechnology and bioinformatics. Present your findings.

Activity 13.5 STEM

Aim

To design a product which uses cheap, discarded and biodegradable materials to solve oil spills in the aquatic ecosystem

Procedure

1. Work in groups.
2. Search for information on biological products that can degrade oil molecules.
3. Based on the information that you have gathered, design a prototype that uses cheap, discarded and biodegradable materials to solve oil spills in the aquatic ecosystem.
4. Test your prototype and present it in your class.

Importance of Biotechnology in Life

The field of biotechnology has developed rapidly in Malaysia and has improved human lives in both developing and developed countries. Have you ever heard of the first clone sheep called Dolly?

Photograph 13.8 Dolly

13.2.2 13.2.3

Biotechnology is often associated with agriculture, industry, nutrition, medicine and other fields. Rapid development in biology and technology has replaced the old methods with the current and sophisticated approaches in producing many types of products that benefit humans. Besides contributing to increase the yields in food, agriculture and medicine, biotechnology also improves a country's economy specifically in the industrial sector. Table 13.3 shows the contributions of biotechnology to life today.

Table 13.3 Contributions of biotechnology to life

Field	Contributions
Agriculture	• Produce the best livestock and crop breeds. The tissue culture method and cloning technique have expedited plant reproduction. • Produce paddy varieties which give more yield and mature faster. • Animal cloning enables mass reproduction and produces disease-resistant clones. • Use of hormones expedite animal growth and maturity.
Medicine	• Can modify the genetic contents of an individual. • Reduce risk of mental disease. • Prevent specific diseases such as cancer and inherited diseases. • Human with dwarf genetics can have normal children. • Assist mothers with difficulty to conceive.
Forensic	• Can identify criminal based on tissue or body fluid such as blood, semen, skin or hair follicle.
Environment	• Microbes can expedite decay of waste products created by humans. • Microbes can also degrade faeces completely. • Reduce pollution to protect humans and the environment.

Activity 13.6

21ST CENTURY SKILLS

DEBATE

Aim

To debate on the effect of biotechnology on humans, animals and the environment

Procedure

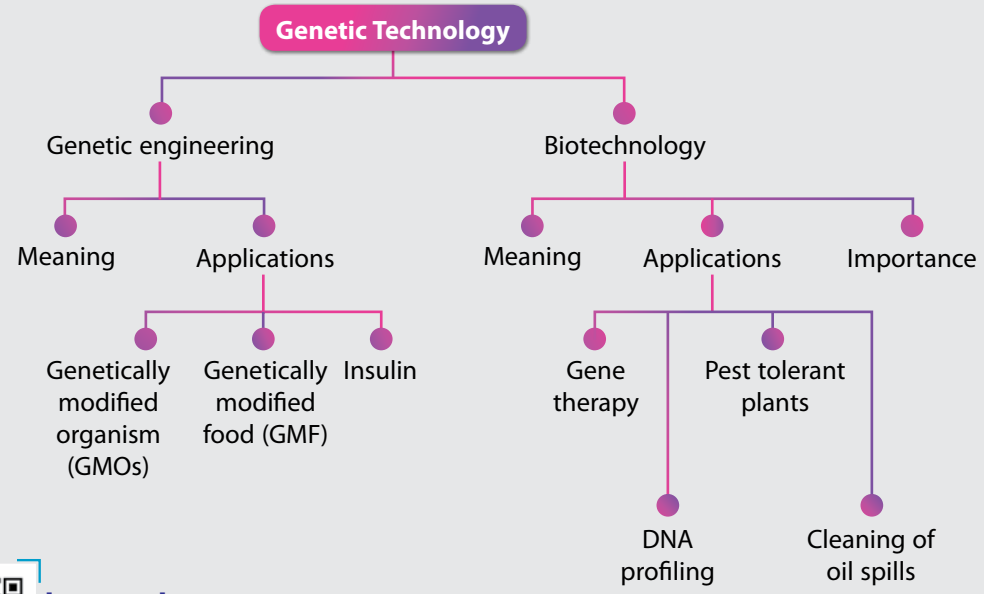
1. Divide the class into two groups.
2. Search for information on the effects of biotechnology on humans, animals and environment.
3. Elect a representative for each group. One represents the affirmative group, and another represents the opposing group.
4. Prepare your complete arguments on the topic entitled "Biotechnology brings more positive effects to humans, animals and environment".
5. Carry out the debate in your class.

Formative Practices 13.2

1. How can the DNA of an individual with a genetic disease be changed?
2. Provide **two** benefits of biotechnology to life.

13.2.3

Memory Flashback



Interactive Bio 13

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of genetic engineering		
Meaning of GMOs and GMF		
Application of genetic engineering in the production of GMOs, GMF and insulin		
Meaning of biotechnology		
Application of biotechnology in life		
Importance of biotechnology in life		

Summative Practice 13

1. Damage to gen X of the pancreatic cell prevents the production of protein X. This causes blood glucose level to increase and cannot be controlled. However, the genetic engineering technique has enabled large-scale production of protein X by the following steps:
(P, Q, R and S are not arranged in the right sequence)

P: Bacteria that carries gene X is cultured in a large quantity
Q: Normal gene X is removed from human pancreatic cell
R: Gene X is inserted into a bacterial cell
S: Protein X is extracted and purified

(a) Name protein X.

(b) Use letters P, Q, R and S to show the correct sequence in steps to produce protein X.

(c) Give **two** reasons why bacteria are commonly used in the genetic engineering technique.

(d) Give **two** examples of medical products produced by genetic engineering.

(e) In a murder case, a knife with blood stains was found by police at a crime scene. By using DNA extracted from the sample on the knife, DNA profiles of the victim and three suspects were obtained as shown in Figure 1.

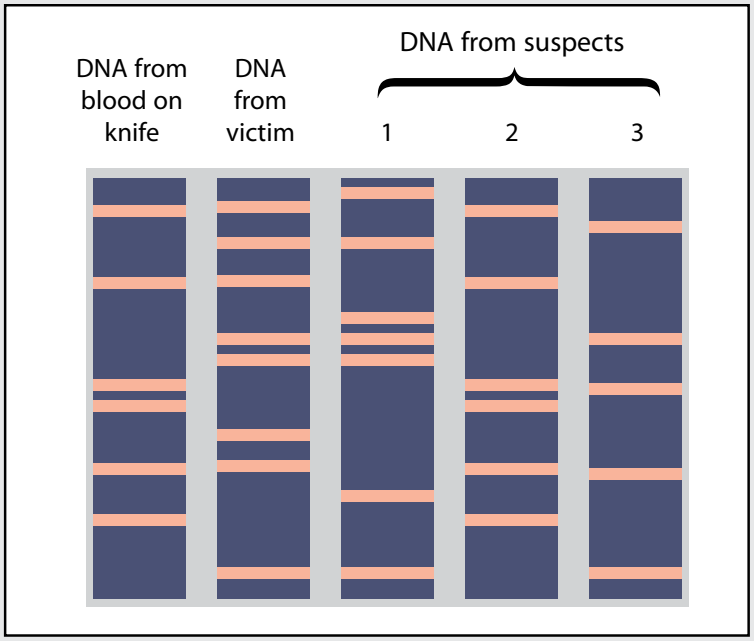


Figure 1

(i) Among the three suspects 1, 2 and 3, who is most likely the murderer? Give reasons.

(ii) Is this DNA profiling technique useful? Why?

(iii) One of the identical twins is found to have committed a crime. Can both of them be distinguished by this DNA profiling technique? Explain.

2. (a) Discuss the advantages of genetically modified food towards human lives.

(b) A bacterial strain can synthesise a protein with a known benefit to humans. Explain briefly how a geneticist can acquire the bacterial gene and mass produce it immediately.

(c) Explain why a plant variety which is modified by genetic engineering to tolerate herbicide can be a threat to the environment.

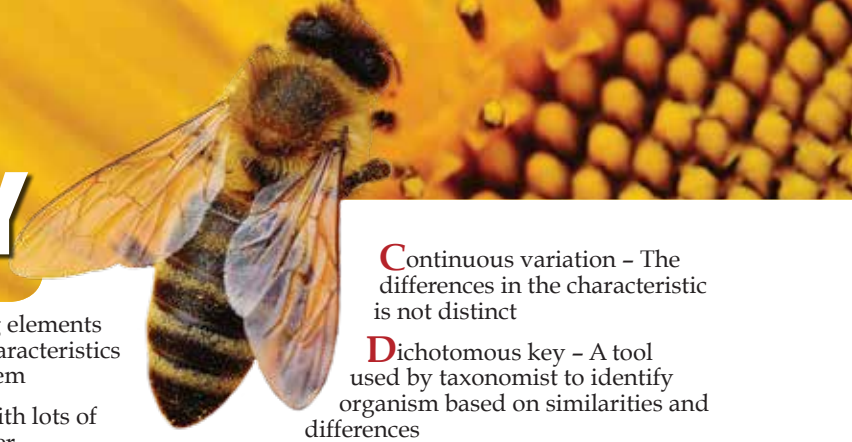
21st Century Mind

3. Recently, many genetically modified food (GMF) have been produced and are available in the market. As a representative of a non-governmental organisation (NGO), you proposed that GMF should be labelled as shown in Photograph 1 and with its contents printed. Justify your proposal.

Photograph 1

4. The illegal ivory trade is rampant in some African countries. It is estimated that 50,000 African elephants have been killed to get their tusks. The authorities find it difficult to identify the real syndicates who run the illegal trade since most suspects caught were non-syndicate members but individuals who merely transport the ivory. Recently, a group of scientists have been actively producing DNA profiles of elephant tusks confiscated by the authorities. In your opinion, explain why communities have so much interest in elephant tusks and how DNA profiling technique can eradicate the smuggling of elephant tusks.

GLOSSARY



Abiotic components – All the non-living elements including their physical and chemical characteristics that can affect an organism in an ecosystem

Aerenchyma tissues – Spongy tissues with lots of air spaces that assist plant to float in water

Allele – An alternative form of a gene for a specific trait that is located on the same locus of a pair of homologous chromosomes

Annual plant – A plant that has only one life cycle for a season or a year

Autotrophic plant – Plant that can form its own food by synthesising complex organic compounds from simple inorganic substances

Auxin – Plant hormone that is involved in cell growth at tip of shoot

Aspect – Directions of wind blows and the rays of sunlight

Biennial plant – A plant which takes two years with two seasons of growth to complete its biological life cycle

Biochemical Oxygen Demand – Total amount of oxygen needed by microorganisms such as bacteria and fungi to decompose organic materials in water

Biodiversity – The variety of living organisms such as microorganisms, animals and plants that interact with one another

Biotechnology – A field which utilises technology or method to manipulate organism for the production of biological product

Biotic components – Living components in an ecosystem

Capillary action – Water potential to move upwards against gravity in the stem with the help of adhesion and cohesion forces

Chemotropism – Plant response to chemical

Chlorosis – A condition in which leaves turn yellow due to insufficient production of chlorophyll

Commensalism – An interaction that provides benefits to only one organism without causing any harm to other organisms

Community – The populations of all organisms from different species living in the same habitat whilst interacting with each other

Compensation point – Level of light intensity when rate of respiration equals to the rate of photosynthesis

Continuous variation – The differences in the characteristic is not distinct

Dichotomous key – A tool used by taxonomist to identify organism based on similarities and differences

Discontinuous variation –The differences in the characteristic is distinct

Ecosystem – A few communities that live together in a habitat and interact with each other including non-living components (abiotic) such as water, air and soil

Ecosystem diversity – The biotic community and ecological process in ecosystems on the land, in the sea and other aquatic environments

Gene – Basic unit of inheritance that consists of a segment of DNA located at specific locus of a chromosome

Genetic diversity – The genes variation of an individual within a population and the genes variation between different populations of the same species

Genetic engineering – A gene manipulation technique to modify genetic material of an organism to produce new combination of genes

Geotropism – Plant response to gravity

Guttation – Secretion of water droplets through a special structure at the end of leaf veins without involving the stomata, caused by a high root pressure

Halophyte – A plant that is adapted to live in an area which is very hot, dry and has minimum water such as in a desert

Herbarium – A specimen collection from plant which are preserved through a certain method

Heterotrophic plant – A plant that depends on other organisms for nutrients

Hybrid – A product of mating between two purebreed varieties

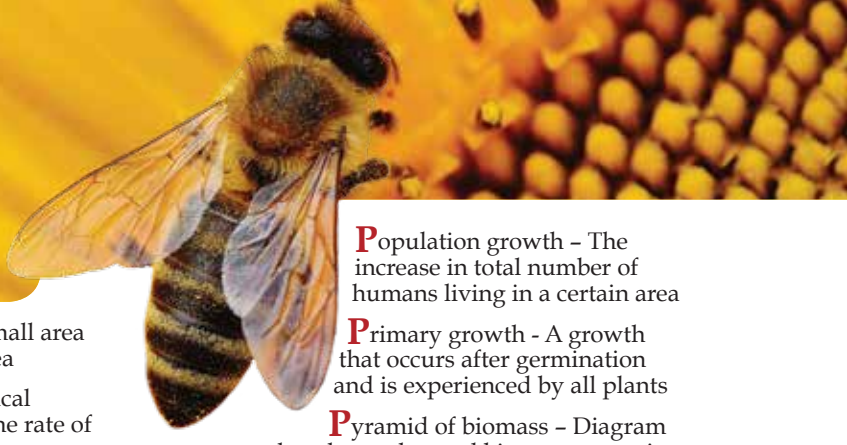
Hydrophyte – An aquatic plant that lives either on the surface or submerged in water

Hydrotropism – Plant response to water

Lignin – Organic polymer that provides mechanical support to plant tissues

Mesophyte – A plant that needs only a moderate amount of water

Micro balance – A balance that can measure accurately a very small mass up to 0.1 milligram



Microclimate – Climatic condition for a small area which is different from the surrounding area

Mutagen – A physical, chemical or biological agent that can cause mutation or increase the rate of mutation to a dangerous level

Mutualism – An interaction which gives benefits to both organisms

Nastic response — Responses of certain parts of a plant that is independent of the direction of the stimulus

Niche – The role of an organism in an ecosystem which includes its behaviour and interactions with biotic and abiotic components in the surrounding of its habitat

Non-vascular plant – A plant that does not have a transport system

Nucellus – A central part of a plant ovule which contains an embryo sac

Nutrition – A way for an organism to obtain nutrients and energy from the food for its life processes

Ovule - A structure that gives rise to and contains the female reproductive cells; it is a structure in a flower that is formed inside the carpel

Parasite – An organism that benefits from its host yet causes harm or even kills it

Pathogen – An organism that causes disease

Pectin – A material found in cell wall of plant

Perennial plant – A plant that lives more than two years

Phylogeny — The evolutionary history of a species or a group of organisms that are genetically linked

Phytoremediation — Treatment method which uses plants for the purpose of degradation, extraction or elimination of pollute substances from soil and water

Phototropism — Plant response to light

Pneumatophore – Short root projections from the soil surface for aeration in water-submerged areas

Pollination – A process that involves transfer of pollen grain from anther to stigma

Population – A group of organisms of the same species that live in the same habitat

Population growth – The increase in total number of humans living in a certain area

Primary growth - A growth that occurs after germination and is experienced by all plants

Pyramid of biomass – Diagram that shows the total biomass per unit area of all organisms in every trophic level

Pyramid of number – Diagram that shows the number of organisms in every trophic level of a food chain

Root pressure – Pressure that forces water in root xylem vessels absorbed from soil to move up the stem of a plant

Species – A group of similar organisms, able to interbreed and produce offspring

Species diversity — Variation and variability of organisms on Earth

Stoma – A minute pore found mostly on the lower surface of a leaf

Taxonomy – A field in biology which involves the classification, identification and naming of organisms in an organised manner

Thigmotropism - A plant response to touch

Translocation – A process of transporting of organic materials such as sucrose, amino acids and hormones in the phloem from leaves to other parts of a plant such as roots and stem

Transpiration – An evaporation of excess water in the form of water vapour by diffusion from the plant to the atmosphere

Tropism — Response of certain parts of plant such as root or shoot towards or away from a stimulus

Vascular plant – A plant that has a transport system

Vascular tissues – Plant tissues that transport water and nutrients to all cells

Xerophyte – A salt-tolerant plant grows in soil or water of high salinity such as mangrove swamps and seashores

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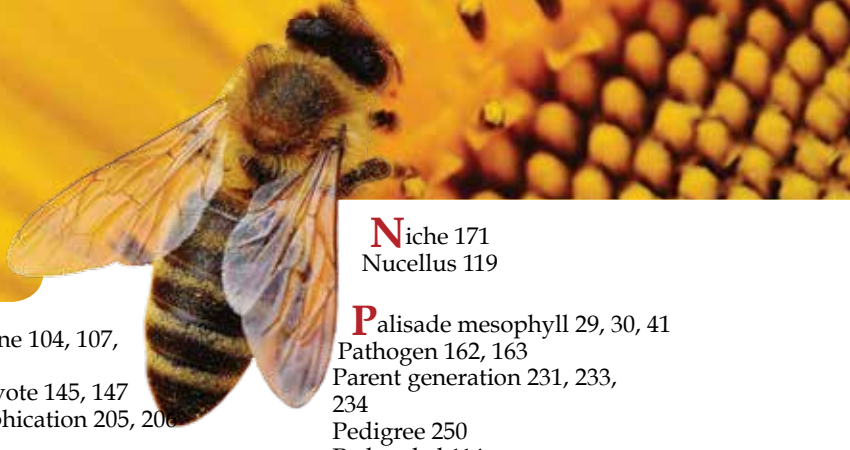

Dengan ini **SAYA BERJANJI** akan menjaga buku ini dengan baiknya dan bertanggungjawab atas kehilangannya serta mengembalikannya kepada pihak sekolah pada tarikh yang ditetapkan.

Skim Pinjaman Buku Teks

Sekolah _____

Tahun	Tingkatan	Nama Penerima	Tarikh Terima

Nombor Perolehan: _____

Tarikh Penerimaan: _____

BUKU INI TIDAK BOLEH DIJUAL